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Heating Piping & Air Conditioning

DESIGN
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JUNE ★ 1943

INDUSTRIAL
COMMERCIAL
AND LARGE
BUILDINGS

305: *Journal Section of the American Society of Heating and Ventilating Engineers*

Preparing the specifications for small arms munitions plants is among the subjects treated this month

CONTENTS . . PAGE 55

There are several important reasons why, among qualified pipe welders, Midwest Welding Elbows have earned a reputation for exceptional dimensional accuracy and uniformity. One reason is because the included angle of 90° or 45° between the machine-beveled ends is always exact . . . both ends are simultaneously machined as shown at the right. The elbow's final sizing in compression makes it possible for the fixture to clamp it in accurate position—so the center-to-end dimension is always the same.

For data on all the advantages of Midwest Elbows . . . and the other Midwest Welding Fittings . . . ask for Bulletin WF-41.

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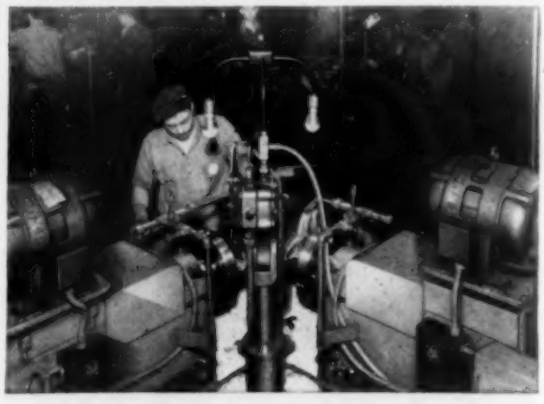
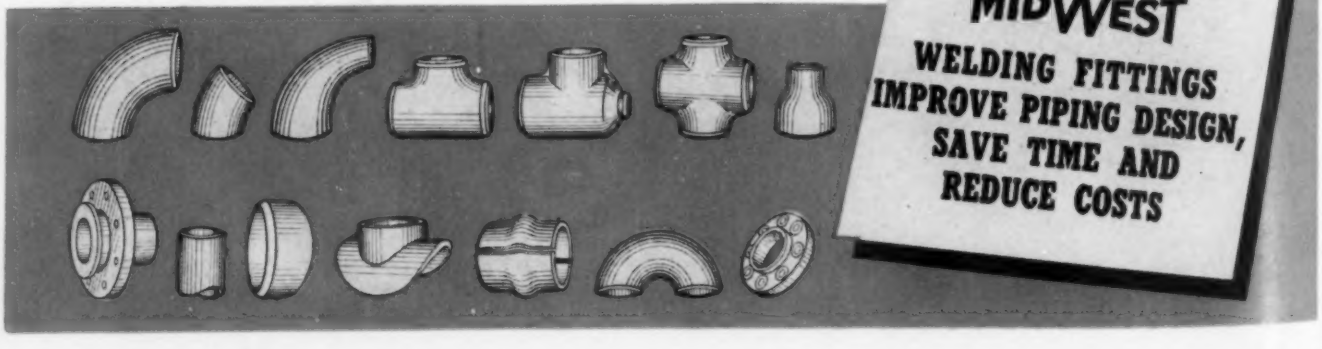


Shown here is one of the machines especially built by Midwest for simultaneously machine-beveling both ends of Midwest Welding Elbows and holding the included angle within extremely close limits. Special fixtures and special tools were also developed for this work. Similar machines with three heads are used for finishing Midwest Tees.



The Editor's Pages

URGE COAL USERS TO STORE FUEL RIGHT NOW

Industrial users of bituminous coal were told last month by Deputy Solid Fuels Administrator Howard A. Gray that the supply of that coal would get "tighter and tighter" as the war progresses. Speaking before the annual convention of the National Association of Purchasing Agents, he advised such users to store as much bituminous coal as could be made available to them this spring and summer.

"Some consumers with low stocks may be hoping to have the Solid Fuels Administration get them out of trouble if they run short. I want to advise all users that, although the Solid Fuels Administration will do everything within its power to prevent a coal emergency from curtailing war activities, their best insurance policy will be coal in their own stockpile. The man who fails to provide for himself when coal is available may not like the kind or size of coal he gets through operation of the government's emergency powers. Nor is the government likely to be particularly concerned about how much it will cost the consumer to get coal by emergency arrangements," he said.

Bituminous coal dealers and consumers, both industrial and domestic, served by Great Lakes docks were also urged by Solid Fuels Administrator Harold L. Ickes to accept delivery of next winter's coal this summer instead of letting it accumulate in huge piles on the lake docks.

He said that summer deliveries are necessary to cut down the size of the coal piles on the docks to save the loss of fuel by spontaneous combustion, and to prevent transportation of coal from the docks to users from becoming congested next winter.

TECHNICAL CHANGES IN L-38 ORDER

Several technical changes in the limitation order controlling production and delivery of commercial and industrial refrigeration and air conditioning machinery were made May 20 by the War Production Board. The amended order L-38—

Permits a producer or dealer to deliver maintenance and repair parts to industrial and commercial establishments in accordance with the controlled materials plan.

Revises the definition of "air conditioning system" to exclude certain types of heat exchanger equipment, which are covered by limitation order L-172.

Revises the definition of "parts" to exclude from its terms material such as refrigerants, lubricating oils, belts, packing, non-metallic filters, etc., which are covered by other orders or for which no priority is required.

Revises the definition of "producer" and "dealer" to include producers and dealers of "industrial type extended surface heating equipment" and "industrial type humidifying equipment."

Substitutes the term "maintenance and repair service" for "emergency repair service" and defines the former to include maintenance servicing as well as emergency servicing to bring such servicing within the scope of the order.

Changes the restrictions on farm milk coolers to include only evaporator coils and condensing units.

Requires the owner of a repaired air conditioning system to dispose of replaced parts through regular scrap channels or to the dealer or producer as a condition of his purchase of new parts.

Prohibits the sale of used air conditioning and refrigerating equipment of 3 hp or larger by any person, except on an authorized order.

POSTWAR PLANS NEED SOUND ENGINEERING

The great majority of predictions on postwar living will become realities after victory, John E. Haines, manager of the air conditioning controls division of the Minneapolis-Honeywell Regulator Co., said in a speech at Boston last month. Most of the products and plans currently proposed are well founded on engineering experience; many, in fact, were well started before the war, he said.

"But," Mr. Haines told the Boston chapter of the American Society of Heating and Ventilating Engineers, "a small minority of planners are predicting fantastic and impractical products and designs for living. Unfortunately, these few dreamers have caught the fancy of the public, which loves to read about this sort of thing." Practicality and sound engineering should supersede appearance, he said.

"Users of automatic heating today wonder why they were ever satisfied with hand fired central heating plants," he continued. "They are well pleased with their automatic heating systems and a large majority of them do not know that improvements can and should be made." Suggesting a more modern, healthful, and economical method of heating, Mr. Haines said that homes built in the postwar era should include zone control.

SPECIAL NIGHT SHIFT FOR "WHITE COLLAR" MEN

The special night shift created recently in the Bridgeport, Conn., plant of Jenkins Bros., manufacturers of valves, has turned out to be a huge success, according to Bernard J. Lee, vice president in charge of manufacturing.

The special shift, from 6 to 11 p.m., Monday through Friday, was designed to attract "white collar" workers already employed in the daytime, offering them an opportunity to participate directly in the manufacture of war materials. They work in the plant as tool designers, toolmakers, and on the machine benches, and include bankers, brokers, attorneys, business executives, salesmen, and bookkeepers.

AIR CONDITIONING HELPS TO SAVE LIFE

In world war II it is common knowledge that progress in medical science has greatly reduced the percentage of fatalities to casualties. And in the progress of medical science, air conditioning is playing a vital role.

Recently, Carrier Corp. received the following comment from an Army air base, one of many in which its air conditioning and refrigeration equipment has been installed as a standard part of hospital facilities:

"The uniformly comfortable low temperature produced by this equipment has been effective in reducing the excessive perspiration of both patient and operating room personnel which is inconvenient during the summer, late spring, and early fall months in this hot, humid climate. This has improved sterile technique and the efficiency and speed of the operating team, and the patient leaves the operating room in a better state of hydration. In the x ray darkroom, it has enabled the technician to work continuously, whereas previously he had to take frequent rest periods because of the excessive heat."

AUBREY ELECTED ACRMA PRESIDENT

W. H. Aubrey, Frick Co., was elected president of the Air Conditioning and Refrigerating Machinery Association last month. Other officers are J. P. Rainbault, General Electric Co., first vice president; D. W. Russell, Airtemp Div., Chrysler Corp., second vice president; and P. A. McKittrick, Parks-Cramer Co., treasurer.

E. T. Murphy, Carrier Corp., was elected to the chairmanship of the ACRMA board of directors.

The Editor's Pages

RECENT AMENDMENTS TO FUEL OIL RATIONING ORDER

An index to amendments Nos. 1 to 50 to the fuel oil rationing order appeared on pp. 171-172 of the April HPAC. Amendments 51-60 were covered on p. 233 of the May HPAC. The following information on amendments 61-65 has been taken from OPA fuel oil industry letters issued last month:

Amendment 61 restricted emergency deliveries to the period before May 1, 1943.

Amendment 62, effective May 13, 1943, provides that a person to whom a ration has been issued for furnishing hot water only to residential premises other than a private dwelling may apply for a substitute ration under the provisions of amendment 46 (change in circumstances or miscalculation of needs).

Amendment 63, effective May 15, provides for summer deliveries in the Pacific Northwest.

Amendment 64, effective May 18, to carry out the new conversion policy, provides revised definition of convertible facilities, as follows:

"Convertible facilities means *any fuel oil burning equipment in premises other than private dwellings*, which may be altered or refitted to use an alternate fuel. However, the equipment is not convertible if one or more of the following conditions exist:

a) An adequate supply of an alternate fuel is not available; or

b) The materials or labor needed to alter or refit the equipment to use an alternate fuel are not available; or

c) The materials or labor needed may be obtained only with unreasonable expense; or

d) The equipment furnishes heat or hot water, or both, to premises located in the states of Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, North Dakota, South Dakota, Nebraska, Kansas, or Missouri and the allowable ration for the entire heating year is less than 10,000 gal; or

e) The equipment furnishes heat or hot water, or both, to premises located in the states of Florida, Georgia, Idaho, Oregon or Washington.

"No ration shall be issued or used for the operation of convertible facilities for furnishing heat or hot water, or both, except to the extent necessary to operate these facilities until the earliest date when conversion can be completed."

By this amendment, auxiliary and supplemental rations will no longer be denied to private dwellings because of "convertibility."

Amendment 65, effective May 27, provides:

1) On and after June 1, in thermal zones A and B, a *hot water ration* may be issued for water heating equipment, even though central heating equipment using an alternate fuel is available for the purpose. Such a ration may not extend beyond August 31, 1943. The same type of ration may be issued in thermal zones C and D, on and after May 15, for a period not beyond September 30, 1943.

2) On and after June 1, in thermal zones A and B, a *domestic cooking ration* may be issued for cooking equipment even though cooking equipment using an alternate fuel is available for the purpose. The ration shall be granted for the necessary fuel oil, for a period not beyond August 31, 1943. The same type ration may be issued in thermal zones C and D, on and after May 15, for a period not beyond September 30, 1943.

CLARAGE FAN NAMES WARE PRESIDENT

Roland R. Ware, for the past 13 years general manager, was elected president of Clarage Fan Co. at the annual meeting held last month. He succeeds Harry Clarage, who was named chairman of the board of directors.

Other officers elected were S. A. Schaeffer, vice president, C. A. Kline, secretary, and C. C. Wheeler, treasurer. In addition to being president, Mr. Ware will continue to be general manager.

Clarage is operating at maximum capacity manufacturing air handling and air conditioning equipment to meet vital war needs. During the last three years the volume of business handled by this company has more than tripled.

PIONEER OF COMBUSTION EFFICIENCY PASSES

Joseph Weller Hays, combustion engineer and founder of what is now the Hays Corp., died April 22 at the age of 75.

Probably no man in America was so well known to boiler room operators and thousands of others in industry as Joe Hays. A practical operating engineer, consultant, writer, lecturer, inventor, teacher, he touched intimately the lives of thousands working to obtain better combustion conditions in the steam plants of the nation. His book, How to Build Up Furnace Efficiency, now in its 18th edition with a distribution of over 125,000 copies, is an "operating bible" for boiler room crews.

FLOOD WATERS SHRINK OIL MOVEMENTS TO EAST

Widespread disruption of transportation by floods in the midwest and southwest will shrink the movement of oil to the eastern seaboard "by at least a fifth and may for a few days cut that traffic nearly in half," the Office of Defense Transportation said May 22.

Washouts of rail facilities, the break in the "Big Inch" pipe line, time lost for repairs of roadbeds, bridges, and the pipe line, and the time required to get solid train operation back on its fast schedules after full repairs are made, are the contributing factors.

INDUSTRIAL ADVERTISERS OUTLINE POSTWAR PRINCIPLES

The National Industrial Advertisers Association has issued a "declaration of postwar principles," stating the 10 basic principles upon which they feel a secure postwar economy can be built. The association declares that the maintenance of a high level of employment is the major responsibility of industry and that the only feasible means of paying huge war debts within a reasonable period of time is by the attainment of a high level of prosperity for everyone.

WESTINGHOUSE ANNOUNCES POSTWAR POLICY

A postwar policy "with both feet on the ground" was recently outlined by T. J. Newcomb, sales manager of the Westinghouse electric appliance division, in an open letter to 32,000 electrical dealers throughout the nation.

"Our postwar planning in the interests of consumers and dealers covers two stages," Mr. Newcomb reported. "First, when the war is over we plan to get into production fast on essentially those products you sold just before the war. We shall improve them but won't experiment with radical changes."

The second phase, he explained, is "bring along the revolutionary new developments as quickly as they can be proved."

Mr. Newcomb's letter opened with the question: "When peace comes and the postwar planning you're hearing so much about can be expressed in actual products—what will you, as an electrical merchant, be most interested in? We believe you will want a line of products which you can get for actual selling—fast," the letter continued.

Heating Piping & Air Conditioning

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and Large Buildings

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IN THIS ISSUE

Volume 15 **June, 1943** **Number 6**

The Editor's Pages (news and comment).....front section 51

Radiant Heating and Cooling for a New Plant Cafeteria, by T. Napier Adlam..... 277

Bureau of Mines Tests Colloidal Fuel Operation..... 280

Sam Lewis' Page..... 281

Preparing the Specifications for Small Arms Munitions Plants, by John J. Woolfenden..... 282

Fuel Saving Methods, by C. W. Kimball..... 287

What Should Plants Look for in the Way of Scrap?..... 288

7000 Tons of Refrigeration Help to Make It Hot for Herr Hitler, by J. C. Tweedell..... 289

Air Conditioned Aircraft Plant Has Walls That "Breathe" So As To Avoid Condensation Troubles..... 290

How Rations for Fuel Oil Will Be Reissued by OPA..... 292

New File Card Devised by Local Board Simplifies Reissuance of Oil Rations, by E. M. Mittendorff..... 294

Water Sprayed Direct Expansion Coils—Their Theory and Characteristics, by William Goodman..... 295

A History of Piping, by M. A. Hasselmann..... 300

Improves Oil Combustion With Photo-Electric Smoke Alarm, by Barney Meyer..... 303

Automatic Valve Control Governs Flow in War Plant Piping Systems, by B. M. Mills..... 304

Equipment Developments .....back section 127

Trade Literature.....back section 133

Useful Information.....back section 140

Coming Events.....back section 146

Index to Advertisers.....back section 148

Front cover—Executives of Smith, Hinchman & Grylls (Amedeo Leone, H. L. Walton, and Wallace S. MacKenzie) studying a plan for a small arms munitions plant. Cardboard templates for each machine were cut out and assembled into departments which were in turn assembled into production units, thus establishing rough building shapes.

Journal Section of the American Society of Heating and Ventilating Engineers

Graphical Method of Calculating Heat Losses, by Paul D. Close.. 305

Field Study of Comfort Reactions of Apartment Dwellers Under Fuel Oil Rationing, by Sallye Hamilton..... 311

Final Values of the Interaction Constant for Moist Air, by John A. Goff, J. R. Andersen, and S. Gratch..... 319

Semi-Annual Meeting at Pittsburgh..... 325

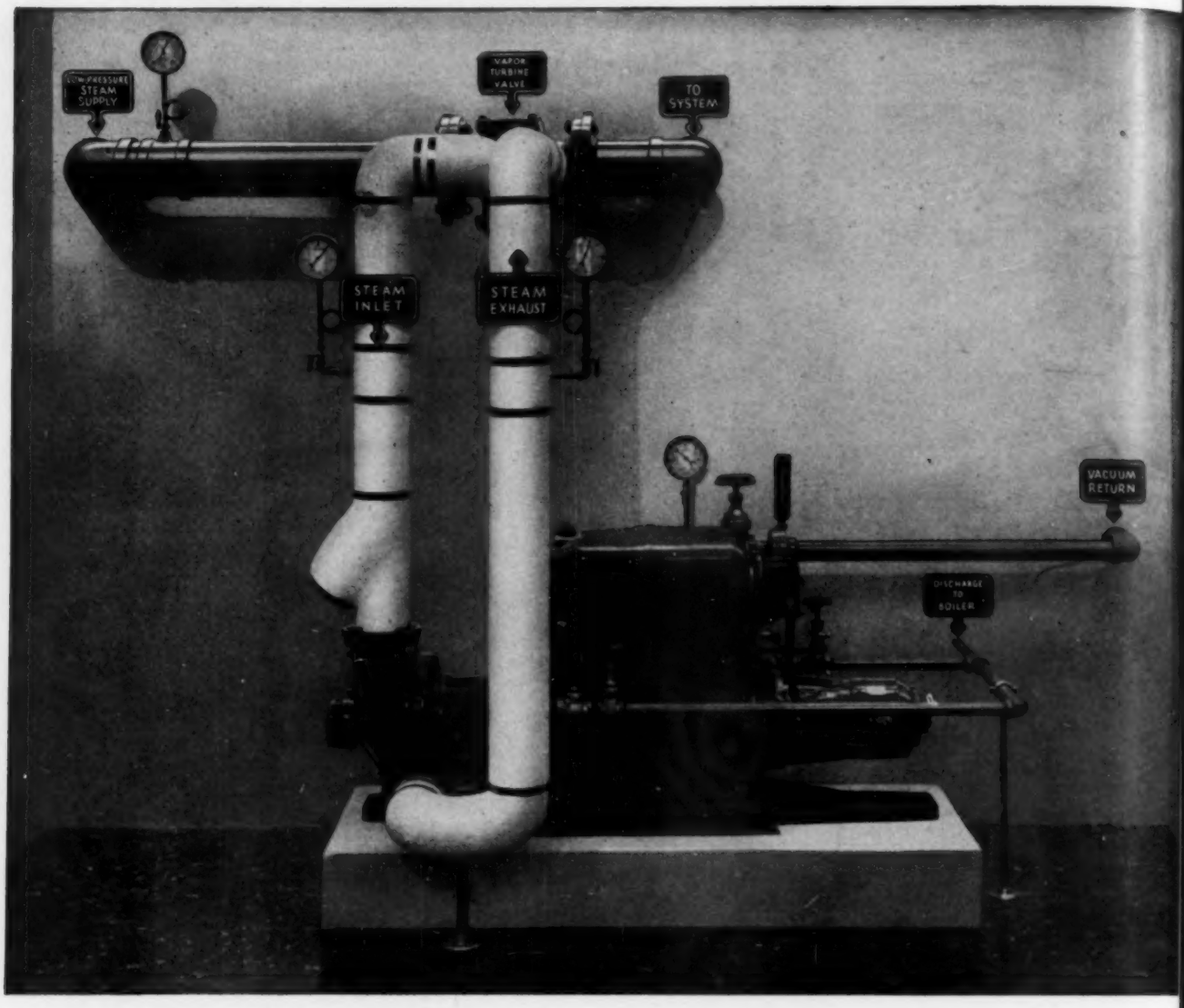
Summary of Local Chapter Meetings..... 327

Candidates for Membership..... 329

Candidates Elected..... 330

Officers, Council, and Committees..... 331

Interrupted Electric Service will not stop this NASH Heating Pump!



In Hospitals, Greenhouses, Schools, Public Buildings, Theatres, wherever heating systems must not fail, install the Nash Vapor Turbine, for it is independent of electric current failure, and continues to operate as long as there is steam in the system.

This is because the prime motive power of this economical pump is a special steam turbine, controlled by a unique "Vapor Turbine Valve", which automatically bypasses from the heating main a small portion of steam, the exact amount necessary to develop the power needed to remove the condensate and maintain the required vacuum on the system. Even this small amount is passed immediately back to the mains, and goes on to the system with little heat loss. This pump operates on any system, high or low pressure.

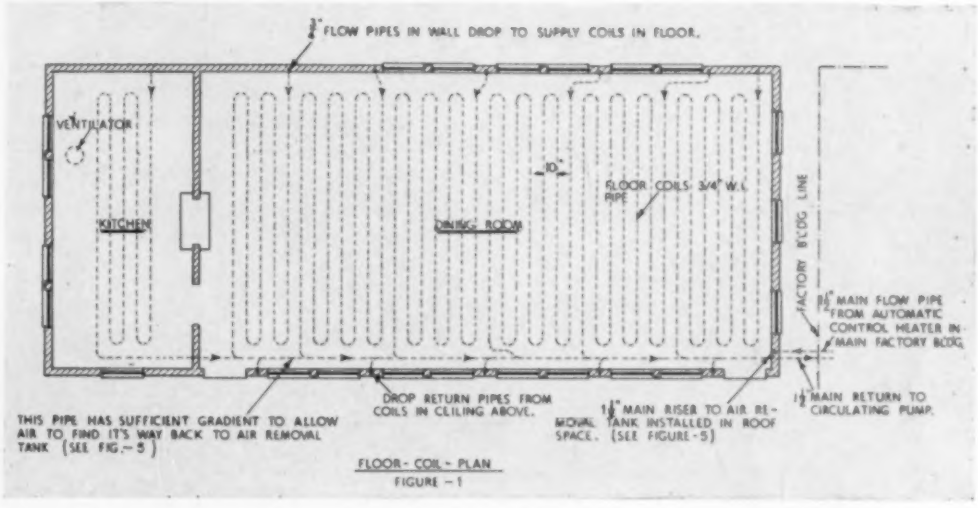
The Vapor Turbine is a most economical pump, for the elimination of electric current does away with current cost, the largest single item in the operation of an ordinary return line heating pump. Bulletin on request.

THE NASH ENGINEERING COMPANY

205-A WILSON ROAD, SOUTH NORWALK, CONNECTICUT, U. S. A.

Radiant Heating and Cooling for a New Plant Cafeteria

T. Napier Adlam Explains Installation of Floor and Ceiling Pipe Coils and Methods of Control


FLOW PIPES IN WALL DROP TO SUPPLY COILS IN FLOOR.
VENTILATOR
KITCHEN
DINING ROOM
10"
FLOOR COILS 3/4" W.I. PIPE
FACTORY BLDG LINE
MAIN FLOW PIPE FROM AUTOMATIC CONTROL HEATER IN MAIN FACTORY BLDG.
MAIN RETURN TO CIRCULATING PUMP.
DROP RETURN PIPES FROM COILS IN CEILING ABOVE.
MAIN RISER TO AIR REMOVAL TANK INSTALLED IN ROOF SPACE. (SEE FIGURE-5)
THIS PIPE HAS SUFFICIENT GRADIENT TO ALLOW AIR TO FIND IT'S WAY BACK TO AIR REMOVAL TANK (SEE FIG.-5)
FLOOR-COIL-PLAN
FIGURE-1

SUMMARY—If you had to name one topic that invariably is brought up for a lot of discussion in any conversation about postwar developments and the future of heating and air conditioning, you'd probably say "radiant heating." We've run many articles on this subject, yet we can't seem to give HPAC's readers their fill. . . . Mr. Adlam, chief engineer of the Sarco Co., Inc., has had as much or more actual experience with such jobs as any other engineer; he describes here a radiant heating—and cooling—installation in a new industrial plant cafeteria, which has both floor and ceiling pipe coils. He explains in detail just how the coils were installed, and the functioning of the controls is carefully discussed.

WHEN DESIGNING the radiant heat system for the new cafeteria in an industrial plant, the author had two or three objectives to take into consideration. The main object, of course, was to provide comfortable temperature conditions for the occupants in winter, but in addition to this, there was the hope that the installation would provide an adequate cooling effect in the summer. While the radiant panels are provided with these two principal ideas in mind, the equipment was also designed so that a series of extended tests can be made with various types of comfort controls. In other words, the building will eventually be used for research work in connection with radiant heating and radiant cooling.

The building is of frame construction with the sides covered with asbestos weatherboard on wood sheathing. The roof construction is slate with wood sheathing on rafters. Since the building is exposed on all four sides and has quite a lot of glass surface, the warming of the floor alone would not be sufficient to give adequate comfort conditions in extremely cold weather without making the temperature of the floor surface too high for "foot comfort." To provide sufficient heated surface to raise the mean radiant temperature of the room to the required degree, coils were placed in the ceiling of the main cafeteria but not in the kitchen.

Each Coil Has Flow Valve

Fig. 1 illustrates the outline of the coils inserted in the floor; these coils were constructed of ¾ in. wrought iron pipe spaced on 10 in. centers. All joints were welded. To insure an equal distribution of heat, the flow of water through each coil is permanently controlled by a flow valve, illustrated in Fig. 3A. In addition to the flow valve, an isolating lockshield valve was inserted in case it is desired to shut off any coil independently.

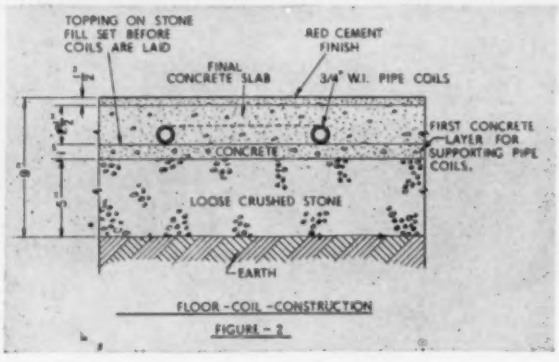
How Floor Coils Were Installed

Fig. 2 gives a part section of the floor construction showing how the coils were embedded in the concrete above the loose crushed stone. The loose crushed stone was first laid on the earth and then a layer of concrete 1 in. thick was finished off with a level surface. The coils were then placed in position and all connected pipes and mains welded.

The coils and mains were carefully graded to allow air to escape back to the air removal tank, and a hydraulic test was then put on the system to see that all joints were perfectly tight. The test given was a pressure test of 300 psi for 12 hr. After everything had been proved satisfactory, a layer of concrete 2½ in. thick was placed on top of the coils and connecting pipes and allowed to set. The floor surface of the cafeteria was finished with a top layer of red cement ½ in. thick and the floor surface in the kitchen was finished with linoleum.

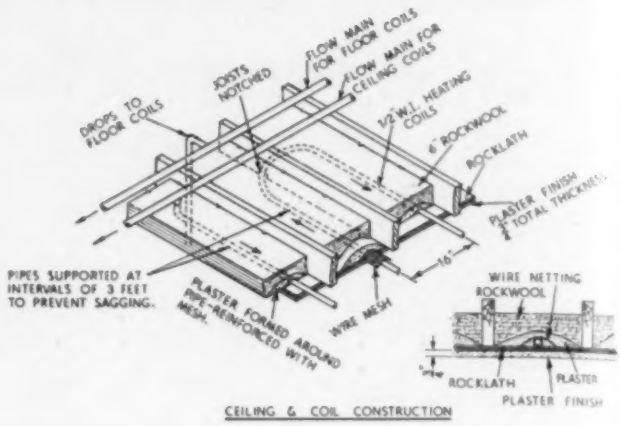
Ceiling Coil Installation

Fig. 3 gives an outline of the pipe coils installed in the ceiling of the cafeteria. These coils were constructed with ½ in. wrought iron pipe spaced 16 in. apart so that one pipe is placed in the center of each



FLOOR-COIL-CONSTRUCTION

FIGURE-2



CEILING & COIL CONSTRUCTION

FIGURE-4

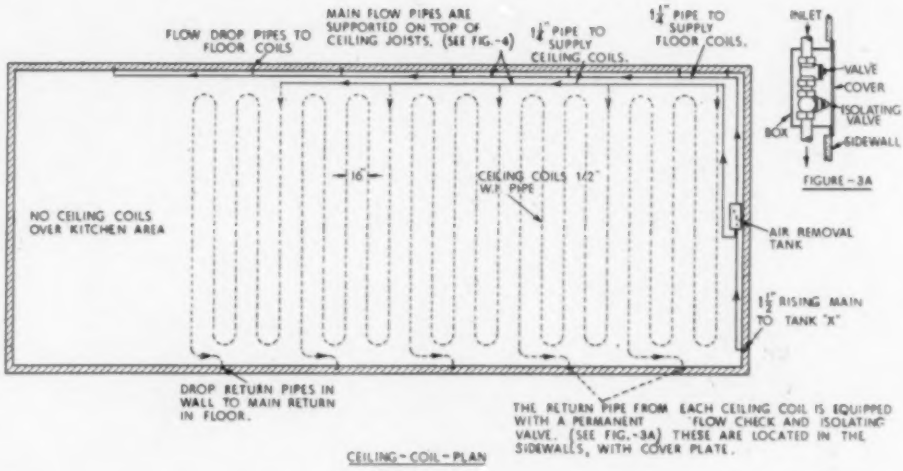

FLOW DROP PIPES TO FLOOR COILS
MAIN FLOW PIPES ARE SUPPORTED ON TOP OF CEILING JOISTS. (SEE FIG.-4)
1 1/4" PIPE TO SUPPLY CEILING COILS.
1 1/4" PIPE TO SUPPLY FLOOR COILS.
INLET
VALVE COVER
ISOLATING VALVE BOX
SIDEWALL
16"
CEILING COILS 1/2" W.I. PIPE
NO CEILING COILS OVER KITCHEN AREA
AIR REMOVAL TANK
1 1/2" RISING MAIN TO TANK "X"
DROP RETURN PIPES IN WALL TO MAIN RETURN IN FLOOR.
THE RETURN PIPE FROM EACH CEILING COIL IS EQUIPPED WITH A PERMANENT FLOW CHECK AND ISOLATING VALVE. (SEE FIG.-3A) THESE ARE LOCATED IN THE SIDEWALLS, WITH COVER PLATE.

FIGURE-3A

CEILING-COIL-PLAN

FIGURE-3

joist, as illustrated in Fig. 4. The ceiling was constructed with rocklath on joists and a total plaster finish ¾ in. thick. The ceiling coils were supported at intervals along their length to prevent sagging. The coils were carefully leveled and tested before adding the rocklath. After the rocklath was installed and the ceiling plaster added, the coils were then covered on top with plaster which extends the full distance between the joists. The plaster was reinforced with wire mesh to prevent crumbling and to help conduct the heat.

The purpose of the plaster around the pipes is to transmit the heat over the whole of the ceiling surface to give a more even temperature. After the plaster around the pipes was set, the spaces between the joists were filled with rockwool to a thickness of 6 in. The flow pipes supported on the joists and all other pipes and fittings in the roof space are well protected with insulating material.

Air Removal Tank

Fig. 5 illustrates the air removal tank and automatic air eliminator which are in the roof space above the cafeteria. The purpose of this tank is to insure that all air is eliminated from the water before the water passes into the smaller pipes of the heating coils. As the water rising in the pipe *X* flows into the tank, any entrained air will be separated and rise to the top of the tank where it will be released through the automatic air eliminator. Without the tank it would be possible for air to be carried through to the coils; this would greatly retard the efficiency.

Ceiling Coils Only Used for Cooling

The principal reason for having two flow connections from the tank is to enable the ceiling coils to be operated with cooling water in the summer. At the same time the floor coils can be isolated by closing valve *A*. When radiant surfaces are being used for cooling effect during hot weather, it is very unwise to cool the floor because a cool floor will create an uncomfortable condition and many of the occupants will suffer from cold feet even though the ambient air temperature may be fairly high. The rapid conduction of heat from the feet to the cold floor not only creates the discomfort of cold feet; it has also been found to bring about rheumatic pains and other ill effects. The only safe way to produce a cooling effect by radiant heat methods is to cool the ceiling or the side walls. Hence, the reason the ceiling only in this building is to be used as a cooling surface.

Method of Heating and Cooling

Fig. 6 illustrates the equipment used for both heating and cooling the circulating water and also the present method adopted to control their temperatures. An open top supply and expansion tank is installed at a sufficiently high level to keep the system full of water. This tank is fitted with a float controlled valve to maintain just enough water in the tank to completely fill the system when cold. Sufficient space is allowed above the controlled level of the water to take care of the expansion of the water as the temperature is raised.

The principal reason for having an open tank system is to enable a non-freezing solution to be used. In normal times the cafeteria and the factory may be left without heat over weekends and there will be danger due to frost. It also may be found desirable to use a refrigerant for circulating a cold liquid for cooling in summer.

A standard type circulator is used to force the water through the system and a standard indirect steam

heater is used to raise the water to a predetermined temperature which is controlled by the thermostat *T*. The temperature of the water leaving the indirect heater *H* is maintained at approximately 125 F and this mixed with a portion of the return water from the coils in the blender insures the correct temperature of the water entering the ceiling and floor coils. The blender valve *B* is controlled by the outside thermostat *S* with a final adjustment effected by the room thermostat *R* acting through the auxiliary bulb *F*, as indicated in Figs. 5 and 6.

The actual functions of the individual units of the heating and control system are as follows:

Steam, supplied from the factory heating system at a pressure of 3 to 5 psi, passes through the thermostatically controlled regulator valve *V* and heats the water in the indirect heater *H* to a temperature of 125 F. This temperature is controlled by a throttling type thermostat *T*, the bulb of which is inserted in the flow pipe from the heater. The circulator *G* circulates the water from the coils in the floor and in the ceiling and forces a portion of this through the indirect heater and a portion directly to the blender valve *B*, where a mixing of the water takes place. The temperature of the water leaving the blender through pipe *D* is controlled by the outside thermostat *S*. This thermostat is placed on the outside of the cafeteria where it is fully exposed to the surrounding air temperature and to radiant rays. In addition to the outside thermostat *S*, a room thermostat *R* is placed in the cafeteria which is subject to the dual effect of air temperature and mean radiant temperature of the walls, ceiling, glass, etc.

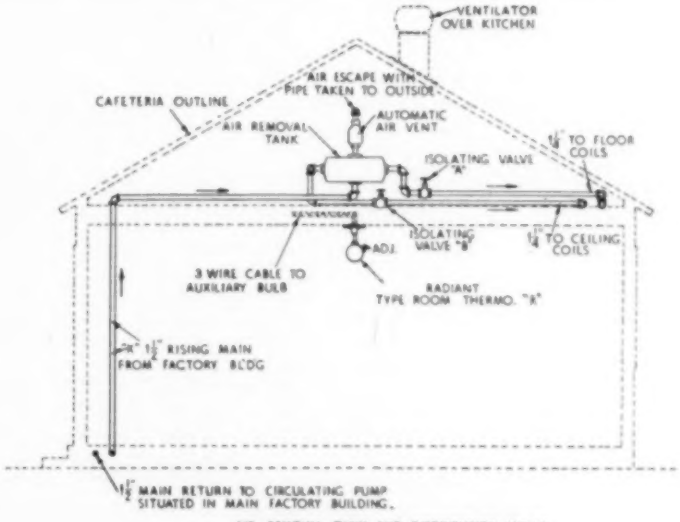
How Control Works

The function of the control is as follows (see Fig. 7):

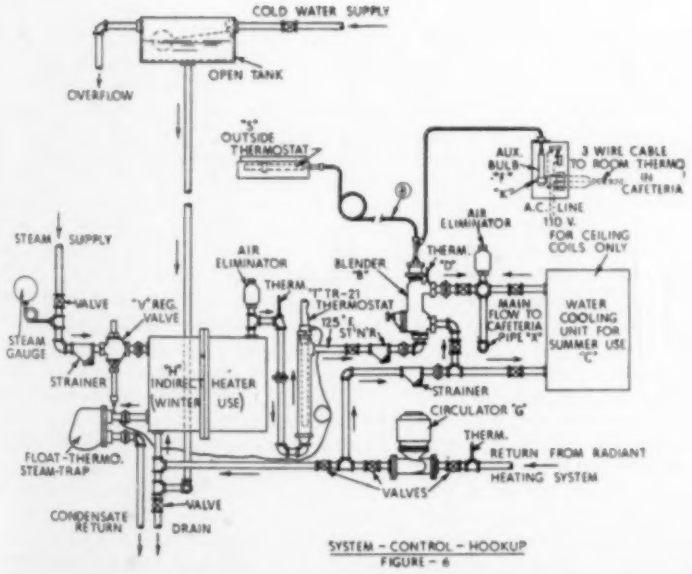
Hot water from the indirect heater enters the valve at connection *1* and a portion of the return water from the coils enters at connection *2*. The blended water leaves the valve at connection *Y*.

As the element *3* is heated by the hot water from the heater, the oil inside begins to expand and pushes the stem *4* outside, causing it to press against the lever *5*. The result of this action is to move the valve disc *6* off the top seat, allowing some return water direct from the pump to enter at connection *2* and mix with the hot water. The mixing takes place in the chamber at *7*.

Since the element *3* is connected by the capillary tube *8* to the outside thermostat *S*, any increase in the temperature of the outside air will cause the enclosed oil to expand and force some of the oil from thermostat *S* along the capillary tubing *8* into the element *3*. The oil thus forced from the outside thermostat to the element *3* will increase the quantity of oil in the latter and cause the stem *4* to move outward. The valve disc *6*,


VENTILATOR OVER KITCHEN
AIR ESCAPE WITH PIPE TAKEN TO OUTSIDE
CAFETERIA OUTLINE
AUTOMATIC AIR VENT
AIR REMOVAL TANK
ISOLATING VALVE "A"
TO FLOOR COILS
ISOLATING VALVE "B"
ADJ.
TO CEILING COILS
3 WIRE CABLE TO AUXILIARY BULB
RADIANT TYPE ROOM THERMO. "R"
"R" RISING MAIN FROM FACTORY BLDG
MAIN RETURN TO CIRCULATING PUMP SITUATED IN MAIN FACTORY BUILDING.

AIR REMOVAL TANK AND DISTRIBUTION MAINS
FIGURE – 5



SYSTEM – CONTROL – HOOKUP
FIGURE – 6

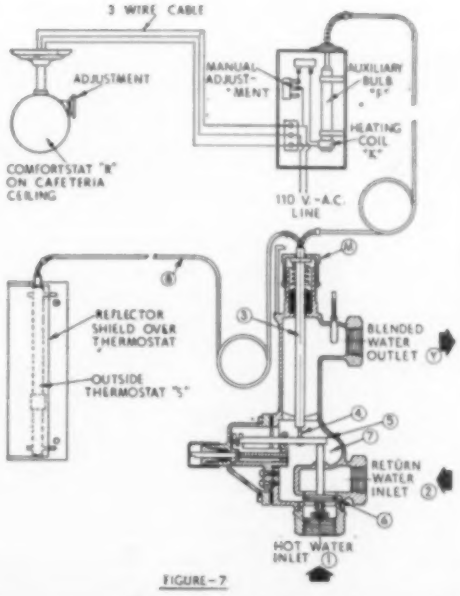


FIGURE – 7

Fig. 8—Wrought iron pipe coils ready for concrete floor

therefore, takes up a position midway between the hot and return water ports, depending upon the temperature surrounding the outside thermostat *S*. Thus, a predetermined relation is maintained between the outside weather conditions and the temperature of the water circulating to the heating coils.

The thermostatic system of the control thus comprises the outside thermostat *S*, the capillary tubing *8*, the element *3*, and the auxiliary bulb *F*, and any change in temperature surrounding either of these will affect the position of the valve disc *6*.

The auxiliary bulb *F* is fitted with an electric heating coil *K* which may be heated more or less according to the function of the room thermostat *R*. Any increase in the temperature surrounding the auxiliary bulb *F* will cause the oil content to expand and force some of this into the thermostatic element *3* and the effect of this will be to move the valve disc *6* closer to the hot water port and thereby reduce the temperature of the water flowing to the radiant heat coils.

While it is possible by the combined action of the outside thermostat *S* and the element *3* in the blender *B* to maintain a predetermined temperature according to the outside conditions, it is occasionally found that this relation does not meet all conditions prevailing outside, since the heat loss from a building depends very much on the radiant effect of surrounding buildings and also that coming to and from the upper stratosphere. The function of the room thermostat *R* is to take care of such changes in conditions and maintain a comfortable condition inside at all times. The room thermostat is constructed with a spherical shell which is affected both by air temperature and radiant rays; more or less current is passed through the heating coil on the auxiliary bulb, depending upon the temperature effect on the sphere.

Adjustments can be made on the auxiliary bulb so that the room temperature can be raised or lowered to suit occupational requirements. The blender valve is also fitted with an adjustment so that by turning the knurled knob *M* the temperature of the water circulating in the coils may be raised or lowered.

Floor Temperatures

Since this system was installed, an outside temperature as low as minus 5 F has been experienced and the conditions have proved perfect. The surface temperature of the floor, even with such extreme weather conditions, never goes above 80 F. With more moderate outside temperatures the surface temperature is not perceptible to the touch.

For test purposes the temperature of the circulating water was raised to 160 F and allowed to operate at this temperature for several hours with no injury to the plaster or other material used in the construction of the building.

The Cooling System

A cooling unit is provided at *C* (Fig. 6) and the temperature of the liquid in the system will be controlled by both an outside thermostat and a room thermostat in the same way as described for the heating. This control, however, is in its experimental stage and, therefore, is not described in this article. Later, when the author has been able to develop this control, it will be the subject of a new article which we hope to be able to give after a number of tests we hope to make in the summer of 1943.

Very little has been done up to the present in controlling the temperature of water for radiant cooling, and the author is hoping to develop a control which will meet this great demand.

BUREAU OF MINES TESTS COLLOIDAL FUEL OPERATION

Colloidal fuel, a mixture of pulverized coal and oil, can be used in many industrial boiler plants of the nation which were designed to burn fuel oil "if careful study and sound engineering practice" are employed in each case, the Bureau of Mines reported last month to Secretary of the Interior Harold L. Ickes, following a one month trial of colloidal fuel in a boiler plant of the Atlantic Refining Co. at Philadelphia.

In the tests, a mixture of 40 per cent pulverized bituminous coal, most of which was ground as fine as talcum powder, and 60 per cent No. 6 (bunker C) fuel oil, was fed to a furnace using a steam atomizing type of burner. The test was run as part of the regular plant routine with existing equipment which was operated by the usual company boiler plant employees. Company engineers cooperated with the bureau in the tests.

No difficulties arose in burning the colloidal fuel in the steam atomizing type of burner used, bureau engineers informed Secretary Ickes. The flame responded smoothly to changes of boiler load and to variations of the amount of air used for combustion. In general, the troubles from the ash of the coal in the furnace were less than anticipated.

Bureau engineers believe that the amount of fuel oil normally consumed by commercial furnaces would be reduced one-third if colloidal fuel is substituted. In the tests just completed, the bureau engineers said that more power generally was required to pump colloidal fuel and, in general, pump capacities probably would be lower when handling the mixture of coal and oil. Because the mixture is abrasive, a varying amount of erosion probably will occur in pumps and burners, they added.

"The amount of settling out of coal from the oil depends on several factors, such as the temperature to which the fuel is heated, the fineness of the coal, and the movement of the fuel," they explained. "Clogging of heaters, screens, meters, and control valves must be watched. In general, none of these difficulties proved serious, with operating routine properly organized. No boiler shutdown occurred from operating difficulties."

These tests show, the Bureau of Mines reported, that this emergency fuel could be the practical solution for many individual cases where the oil supply has been decreased. As with all engineering problems, decisions as to its use should be made as a result of careful study.

SAM LEWIS' PAGE

By Samuel R. Lewis
Consulting Mechanical Engineer
Member of HPAC's Board of Consulting & Contributing Editors

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THERE IS MUCH WE DON'T KNOW

THINKING MEN all over the country are concerned deeply with what may happen in engineering when the war is over. The young men who have been compelled to leave their normal professional occupations to take up war duties will eventually return and must be reabsorbed into industry. The older men who are carrying on in the absence of the young engineers are nearly all overworked in designing plants for war offense and will be tired by the time the boys come home. However, the soldiers will, to a great extent, require re-education in heating and ventilating and in refrigerated air cooling and dehumidification.

Due to the necessity for substituting noncritical materials and for low cost temporary construction, especially in housing projects, there is danger that safe standards of design and construction will be forgotten. Attempts toward regimentation and standardized specifications for mechanical construction as well as for buildings have already caused deterioration in standards and serious waste in money and effort, in my opinion.

Publicity has been given to the idea, for example, that not more than 5 cfm of air from outdoors per person is necessary or even desirable for health and comfort for occupants of buildings. Necessity for air distribution and movement and of temperature control within buildings tends to be ignored. It is not practicable, for example, to reduce the amount of outside air to such low limits in warm weather without refrigeration to control the temperature and without some effective means for controlling relative humidity.

Experienced engineers seem generally to believe that to control the temperature alone, in crowded spaces like school class rooms, it is necessary to move through such rooms a volume of air approaching 30 cfm per person. Except when the outside temperature is snappily cold, much more than one-sixth of the 30 cfm must be taken from outdoors if the interior temperature is to be kept from becoming too warm.

In one large housing project for war workers, where heating was limited to warm air, part of the air blown into dormitories occupied by men and women could be recirculated, according to one engineer, in the interest of comfort and fuel economy; but when the dormitories were occupied by men, women, and children, the rules permitted no recirculation of any part of the air. As a result the occupants suffered severely, with temperatures in the rooms something like 30 deg warmer at head level than at knee level.

The methods of computation in general use for refrigerated air conditioning have been criticized as too detailed and refined, and hope has been expressed that some simpler, quicker, and reasonably effective methods for computing the capacity for single room units may be developed. If two and two make four, the layman wonders—not unnaturally—why work out with a microscope the components that add up to the first two of the two and assume by guess, as is common practice, the components of the second two of the two. Thus, glass and wall areas and solar and power heat reception are developed in great detail but leakage and occupancy cannot be defined accurately.

Radiant heating is coming into its own with rapid strides. The layman queries whether there is any truth in the fear that panel heating does not account for the extra radiation loss from human bodies due to windows, or whether with radiant heating from the floor, the feet will be too warm, and whether with radiant heating from overhead the dining room table will be a barrier causing cold legs of dinner guests. The engineers of the country are somewhat bewildered concerning any patent restrictions or complications which may attend radiant heating. The effect of expansion and contraction of imbedded pipes for radiant heating on plaster and the influence of carpets and rugs still is questioned. Many heating plants have been operated satisfactorily using radiant hot water and steam pipes, but many also have used recirculated hot air through channels in the building construction. Most of those of both types were designed by guess and operate by good luck.

Some engineers believe that venetian type blinds should be outdoors rather than indoors.

The duty of a heating and ventilating engineer is concerned with seeing to it that buildings are so built that they are fit to heat and ventilate and fit to live in. The responsibility of the heating and ventilating engineer is appallingly great.

FUEL OIL RATIONING

ADVISING FUEL oil rationing boards is a war job that is interesting, to say the least.

An outstanding experience is the earnest and conscientious effort, involving making free inspections and reports on some little bungalow heating system in order to save perhaps 100 gal of oil, expending energy, carfare, gasoline and tires, only to find the rationing board blithely passing out thousands of gallons to neighborhood picture houses with little question or compunction.

Another experience is to see a dear old widowed lady expending several hundred dollars for alleged improvements in the heating system in her old home, taking in roomers, burning coal in fireplaces, and wearing extra wraps all in a patriotic and religious endeavor to do her bit to win the war. Having helped such a lady to endure through the cold weather on around three-quarters of the average fuel oil demand of other years, it makes one's hackles rise to be asked, for example, to endorse an application for extra oil in a small apartment building which is burning oil at double the rate of the preceding year.

Investigation of a large number of cases discloses very few where it is not practicable to return to burning coal. A favorite excuse is that spaces formerly used for coal bins now have been remodeled into leased or otherwise occupied vital living quarters. Generally, the objections to conversion to coal seem to be mere failure to believe, on the part of the owner, that the Petroleum Administration for War seriously means business.

Politics rears its ugly head in some cases, especially as between boards of education and rationing boards, often with severe acrimony; frequently, the recalcitrant school authorities seem to win out. The angle in this case most favorable to boards of education is the difficulty in financing the conversion, which may involve special elections to permit issuing bonds.

It seems to me that if the cost of oil for fuel could be made to reflect the shortage or fear of shortage, the problem of conversion would to a great extent automatically solve itself. As long as an owner finds that oil is costing him less in dollars or labor or inconvenience than coal costs, it is naturally difficult for him to decide to convert.

PREPARING the SPECIFICATIONS for SMALL ARMS MUNITIONS PLANTS

John J. Woolfenden Tells How the Work of Specification Writing for Important War Production Projects Was Accomplished, in an Article of Interest to All Engineers

THE PRESENT firm of Smith, Hinchman & Grylls had its origin in a merger of the firms of Mortimer L. Smith & Son, architects, and Field and Hinchman, engineers. The former was established in 1883, the latter in 1894. Although each firm had attained prominence in its respective field when the merger was effected in 1903 there was no indication that the outgrowth of that association would be what has since become one of the principal industrial architectural-engineering firms in existence. . . . The firm name, originally Field Hinchman & Smith, was changed in 1907 to Smith, Hinchman & Grylls, which is still retained although the founders have passed away and the management is now in the hands of those of a new generation, all of whom have been for years associated with the organization and are carrying on the work in accordance with its long established policy. H. L. Walton is president, Wallace S. Mackenzie is vice-president and treasurer, and Amedeo Leone is secretary. . . . Among the firm's recent activities are new distilleries for Hiram Walker at Peoria, Ill. and in Scotland, as well as an addition to their Walkerville plant in Canada; the rebuilding and modernization of all the Seagram distilleries; and the construction of seven small arms munitions plants for the Army ordnance department, three of which are operated by Remington, one by Federal Cartridge, and three by U. S. Rubber

SUMMARY—Preparation of the specifications for heating, piping, and air conditioning installations is a subject of wide interest and great importance; however, it has been somewhat neglected by engineering societies and publications. For a project of the magnitude of that discussed here, the specification writing must be organized carefully if design and construction is to proceed efficiently so as not to hamper our war effort. . . . . .Mr. Woolfenden, research engineer for the well-known architectural and engineering firm of Smith, Hinchman & Grylls, Inc., writes frankly and fully, and gives many practical ideas on preparing the specifications for both large and small installations. He illustrates his remarks with a few pertinent sketches.

IN THE preparation of specifications, every project carries with it its own problems; while there may be a great similarity between some installations, the probability of any two of them being identical is very remote unless they are intentional duplications.

Brevity, clarity, and simplicity are essential features of a specification. It should say enough, but not more than necessary; ambiguous or indefinite provisions should be avoided, the wording should be definite so that the meaning is unmistakable, and the phraseology should be free from complications. To insure this result, a multiplicity of subordinate clauses and repetition, except for emphasis, should be avoided.

Unless the specification writer has the necessary data to work from and unless he has a clear idea of the results desired and how they can best be obtained, he cannot produce a satisfactory specification. Furthermore, if he has the necessary information, if he is familiar with established practice and applicable laws and codes and the "customs of the trade," if he has an adequate command of language and knowledge of grammar, he cannot fail to accomplish his purpose. In such respects, his requirements are similar to those necessary for the analysis of a mathematical problem.

He must overcome any feeling of awe produced by the magnitude of a project. Steel pipe is still steel pipe and pipe fittings remain pipe fittings, whether the total amounts required measure in the dozens or in millions of units. There is a natural tendency —psychological effect, if you will— that produces the feeling in some individuals that certain projects are too large for them even to attempt to handle. Financially, that may be quite true; but to a competent man with a reasonable background of experience the question of technical ability should not enter into consideration, regardless of the size of the project.

One should recognize his actual limitations and be cautious about exceeding them, but he should not introduce imaginary barriers nor should he fail consistently to extend the real boundaries. Doubt of one's own ability is the sure forerunner of failure. Selfconfidence—and that does not mean overconfidence—is the fundamental essential for accomplishment.

Small Arms Plant a Big Project

The typical small arms munitions plant is not a small project, but it is nevertheless made up of a large number of buildings of various sizes ranging from those smaller than a one car garage to those of a size comparable to an industrial plant. Some, especially those of smaller size, will be duplicates, while others are without counterpart. These buildings are variously situated in a ground area which can be measured in square miles. In fact, there are few projects —other than large hospitals, military posts, or similar institutions and, perhaps, those involving housing on a large scale—which are comparable to a small arms munitions plant and most of those mentioned are usually on a much smaller scale.

If the specifications for the entire project were completed, as a whole, prior to the date of issue, there might be little to distinguish them from those prepared for any other large plant or institution consisting of a group of buildings devoted to different operations. This condition, however, is not likely to exist. In the case of seven such plants for which the writer prepared the specifications for the heating and ventilating, plumbing, fire protection systems, elevators and other mechanical work, also including in at least one case the piping for outside drainage, distribution of water, etc., and the sewage disposal plant equipment, the specifications for the various parts of the work were issued progressively, at different times and, after the first project was under way, there were often two or even three developing simultaneously.

Although these projects were, theoretically and fundamentally, "substantially the same," they were nevertheless different and the similarity of certain features was often just sufficient to make it very easy to confuse one with another.

The Critical Materials Problem

This condition was somewhat complicated by the fact that as time went on the question of "critical materials" was introduced. This simply meant that the use of certain materials — and even apparatus in some cases (on account of the materials involved)—which were specified for a customary purpose at a given time might not be permitted for the same purpose, even in the same plant, at a subsequent time. In fact, notification of such restrictions was often received while some part of the specifications was being written.

Under such conditions, it is obvious that any attempt to change the manuscript or to correct the typed pages, even before binding, would result in chaos and that issue of the specifications would be indefinitely delayed. It was therefore necessary to provide by other adequate means for conformation to the restrictions on materials imposed by the federal government.

Another factor which introduced some variations in the requirements for the individual plants was that the plants were to be in different parts of the country, often several hundred miles apart. It will be readily appreciated that under such conditions climatic differences exist and the effect of these on the heating, ventilating, and air conditioning requirements may be very appreciable.

In this connection, it may be noted that the air conditioning systems installed were for process purposes only and that comfort cooling did not enter the picture.

It must be also borne in mind that speed is "the essence of the contract"; construction work is started at the earliest possible moment and, once under way, no interruptions or delays are permissible. That being the case, the specifications must be issued to the field as required; furthermore, certain materials and pieces of apparatus which involve future shipping dates must be decided upon and ordered at the earliest possible moment, so that the delivery will take place not later than the time when the job conditions render its installation necessary.

Couldn't Work from the Blueprints

Many specification writers "work from the blueprints," i.e., they first prepare the general matter and then, having obtained a set of blueprints in as complete a state as possible, continue their work using the prints as a guide with due regard to the subsequent development of the design. In the case of these projects, no such proceeding was feasible as the work on the specifications and the design proceeded simultaneously —nor was it possible to have the

The typical small arms munitions plant is not a small project

work on the tracings stopped for a sufficient time to have blueprints made, even though a continuous blueprint machine is part of the office equipment.

It was necessary that the drawings and the specifications for any given part of the work be issued as near simultaneously as possible and for that reason the manuscript of the specifications was usually turned in for typing a few days before the work on the drawings was completed.

It may seem from what has been said that the result of such conditions would be hopeless chaos, but such is by no means the case. In fact, at times the work on the specifications proceeded at almost a leisurely pace (relatively speaking), although it must be admitted that at certain stages of the work there was nothing slow about it. The manuscript for the first specification for boilers, for example, which also included the settings and firing mechanisms together with the necessary fans and other accessories, was written complete between 4:30 in the afternoon and 8:15 the same night.

We Had a System

That there was no confusion was due to several factors that might be grouped together and termed "system." The first of these was the cooperation of those engaged upon the design of the systems and their furnishing the necessary information regarding the requirements at the earliest possible moment — not the least of this information being that regarding the dates upon which specifications for the various parts of the work would be required.

This made possible the second factor which consisted of the tabulation of the dates in schedule form, so that in connection with each, a notation could be made of the three other important dates—the date upon which the manuscript was completed ready for typing; the date upon which, after typing, it was returned, with the necessary notations, for final correction; and lastly, the date upon which the specification was issued to the field.

The third factor was the form of the specifications themselves.

When the first project was started, it was evident that the preparation of the drawings and the specifications would be a series of progressive steps and that the issue of the drawings for any part of the work would require the coincidental issue of the corresponding specifications. It was also apparent that all legitimate methods of cutting down the labor involved in the work of preparation of these documents and, hence, advancing the time of issue, must be employed.

Basic Plus Supplementary Specifications

Since the basis of awarding the contract for the work was cost plus a fixed fee, and the amounts could be arrived at with accuracy sufficient for the purpose from the estimated cost of the work and other preliminary data, there was no necessity of complete drawings and specifications for bidding purposes.

In order to avoid the delay which would have inevitably resulted had it been required that the specifications be prepared in accordance with the standard government form, instructions had been issued that the form to be used was that to which we had become accustomed and which had become standard with us, with certain slight modifications.

It was therefore decided that the logical type of specifications to use would be that which included a "basic," or general, specification as the groundwork, with additional "supplementary" specifications issued as required. It was also decided that certain items—such as boilers, which involved future shipping dates, and others such as elevators, which were not directly a part of the work of

other trades—should be covered by complete, separate specifications not related in any way to the basic specifications.

The idea of the basic specification is not new and no originality is claimed for it. It is not, apparently, used extensively; perhaps not so much as it might be or even so much as it ought to be. As some, especially the younger members of the engineering profession and the allied trades,

may not be familiar with it, a brief statement of its nature and the method of application by supplementary specifications will be given.

Basic Specifications

It is obvious that by incorporating in the basic specifications all the descriptive matter and requirements common to all parts of the work for the entire project and by binding with them the general conditions and all other similar documents, an immense amount of duplication can be avoided. In this connection, it is well to note that specific requirements, such as the capacities, heads, speeds and horsepowers of pumps; the capacities of pressure reducing valves, etc.; and sizes, excepting those given as limits, were not mentioned in the basic specifications.

The qualities and types of materials, the standards of workmanship, and the detailed construction of pumps, fans, motors, and other apparatus was however described in detail, much as the manufacturer would describe it in a trade catalog. As a matter of fact, save for the general conditions, etc., which follow the prescribed government form, these basic specifications will apply with equal force and propriety to any project whatever for which such materials and apparatus are required. If published broadcast, without the title page, general conditions, basic bid form, etc., it would be impossible for anyone to determine to what project they may apply or anything about the project to which they do apply other than such information as can be obtained, although at the cost of greater effort and in different form, from current catalogs and technical handbooks.

Supplementary Specifications

The supplementary specifications, on the other hand, applied definitely to certain portions of the work and were specific in their requirements. In general, they were quite short owing to the fact that the general requirements were given once for all in the basic specifications.

For example, in the case of a pump, since the detailed construction and arrangement, method of drive, etc., were covered by the basic specifications, unless some special features were required, it would be necessary to give only the type of pump required and, assuming that it is a centrifugal pump, the capacity, discharge pressure, suction pressure, speed, and brake horsepower, together with the minimum acceptable motor size and the type of starting equipment, unless manually operated, as that type is described in the basic specifications and called for to be furnished "unless otherwise specified."

Preparation of Basic Section

It might be thought that a basic specification prepared "in the dark" under the conditions outlined above would be rather vague and random in its requirements and that a great number of corrections would be found necessary as the construction work progressed. As a matter of fact, while improvements were naturally made in the specifications for the subsequent projects, the basic specifications for the first project showed only one case of superfluity and less than six omissions, mostly of a minor nature. This of course does not take into account changes due to field conditions or to restrictions on the use of certain materials subsequently imposed by the government, as these would have been the same regardless of the nature of the specifications.

As implied above, the first step in the writing of the specifications was the preparation of the basic section. This was done during the time that the features of the design were being determined and, as these specifications incorporated no requirements of size or capacity, they were not correlated with the considerations which governed the design, save in those particulars which concerned the size of the project and its nature insofar as these indicated the types of apparatus and materials which would be required.

These specifications were issued to the field as soon as they were completed so that there would be as much time as possible for the officer in charge to check them over and for the superintendent's staff and the contractors to become familiar with them.

In this connection, it may be noted that all specifications issued to the field were required to be approved by the officer in charge before distribution to the superintendents and contractors. The following tabulation showing the relative times of issue of various portions of the specifications at the beginning of the work and the intervals between these dates, will serve to give an idea of the sequence. For convenience, the first project is designed as "Proj. A" and the second as "Proj. B"; also the words *independent*, *supplementary*, and *specifications* are abbreviated.

1st. Ind. Spec., Proj. A.
(26 days)
2nd. Ind. Spec., Proj. A.
3rd. Ind. Spec., Proj. A.
(13 days)
Basic Spec., Proj. A.
4th. Ind. Spec., Proj. A.
(5 days)
1st. Ind. Spec., Proj. B.
(23 days)
1st. Sup. Spec., Proj. A.
5th. Ind. Spec., Proj. A.
(6 days)
6th. Ind. Spec., Proj. A.
(2 days)
7th. Ind. Spec., Proj. A.
(2 days)
8th. Ind. Spec., Proj. A.
(1 day)
2nd. Sup. Spec., Proj. A.
(4 days)
2nd. Ind. Spec., Proj. B.
(6 days)
3rd. Ind. Spec., Proj. B.
(1 day)
4th. Ind. Spec., Proj. B.
5th. Ind. Spec., Proj. B.
6th. Ind. Spec., Proj. B.
(3 days)
Basic Spec., Proj. B.
1st. Sup. Spec., Proj. B.
(2 days)
3rd. Sup. Spec., Proj. A.
(6 days)
4th. Sup. Spec., Proj. A.
(15 days)
5th. Sup. Spec., Proj. A.
(1 day)
2nd. Sup. Spec., Proj. B.

This tabulation represents only the first few months; thereafter the various supplementary specifications were issued as required. It does not include the three or four addenda issued during the period represented nor the specifications issued in the field.

It must also be borne in mind that the specifications for the plumbing work were, with one or two exceptions, issued at the same time as those for the heating and ventilating systems and that the body of the two specifications combined consisted of from 81 pages for a typical basic specification to six or eight pages for a supplementary specification for a small building, averaging exclusive of the basic specifications probably about 20 to 25 pages.

Furthermore, during the intervals indicated specifications already typed were to be proofread, and in addition anywhere from one to three or four other specifications were in course of preparation—or if the plumbing work be counted separately, double that number.

Naturally, in the subsequent work previous specifications could be used as a guide but on account of the dif-

To expedite mail deliveries, the Post Office has assigned zone numbers to delivery stations in many cities. The number should be used as part of the address. For example, mail to HEATING, PIPING & AIR CONDITIONING should be addressed "HEATING, PIPING & AIR CONDITIONING, 6 N. Michigan Ave., Chicago 2, Illinois," as we are in zone 2 of Chicago.

ferences between the various projects they had to very carefully edited and altered so that the actual saving in time, except in the case of the basic specifications, was much less than might be expected. This was especially true in later projects, when not only were three or more progressing coincidentally but many changes in the materials specified were required in order to conform to federal requirements.

A few comments on some of the features of the basic specifications may be of interest:

Owing to the fact that unforeseen requirements might arise or subsequent developments require workmanship, material, or apparatus be of a more or less special nature or deviate somewhat from the descriptions given, it was provided in the prefatory clauses that the requirements of the basic specifications should govern "unless otherwise specified (in the supplementary specifications) or called for on the drawings." In this way, it was made possible to deviate from the requirements of the basic specifications as might be required to cover an unusual condition, without weakening their force or requiring any modification by a separate supplement issued for the purpose.

In order to cover the cases of small structures, for which a few notes on the drawings would constitute an adequate specification, it was provided that under such circumstances there might be no supplementary specifications issued and that the "basic specifications as defined and modified by the requirements set down on the drawings" should govern.

As the restrictions upon the use of critical materials were constantly changing, provision was made authorizing the use of suitable substitutes as might be required by the officer in charge and subject to his approval.

In order to avoid repetition, it was found desirable to stipulate that the description given for any item in the specifications should apply to all similar items required unless otherwise stated. This provision covered not only apparatus and materials but also workmanship.

To abbreviate still further, the meaning of "equal" and "other approved" as used in reference to makes of apparatus other than those named were defined. It was stipulated that alternate makes should be "of equal standard of construction" to those named and be satisfactory to the officer in charge.

Another clause which is often overlooked was that relating to the determination of the limits of a system when, for example, two systems carrying different pressures unite, as at a pressure reducing valve or flash tank. The separation was made upon the basis of the lower pressure system comprising all parts which *cannot* be subjected to a pressure above that allowable as a maximum for that system and all other parts being considered as belonging to the higher pressure system.

There was also included a provision which the writer believes to be original with him and which he first caused to be inserted in specifications over 30 years ago. At that time, he was supervising construction work for his present employers and found

that the regularity with which small articles and accessories called for by the specifications "turned up missing" was extremely annoying and led to much fruitless argument.

In order to relieve the situation and to remove the cause of aggravation, he formulated a suitable clause for insertion in the specifications. The import of this clause is that "all small loose and detachable parts" which the contractor is required to furnish be kept until the work is completed and then be turned over to the owner's representative and be receipted for by him. As originally written, the receipt was to be in triplicate, the contractor to keep one copy and attach the other two to his request for final payment. Of these, the owner got one and the architect kept the other.

Makes of Materials

As to makes of materials, in any specification the necessity of repeating the names of the manufacturers of typical, acceptable material, takes up both time and space. Some years ago, the writer prepared what might be called a "standard" or "master" list of typical makes of materials, listing therein the various materials as headings and under them giving the names of various manufacturers. Such a list was included in the basic specifications.

This list is not complete but is reasonably comprehensive. The prefatory clauses explain that because any item is named therein it does not follow that it is required for the project, but if it is required the makes named are typical. Further, the makes named are acceptable only if the product complies with all specified requirements.

It is also clearly explained that the mention of any make or makes does not carry with it the implication of preference and that other makes are also acceptable, provided that they are of a standard of construction equal to those named.

The names of the items (titles) and also the names of the makes are arranged in alphabetical order. Such a list, being general, is applicable to any specification which requires apparatus and materials of the types comprising the list. Furthermore, it is easy to correct or alter as required and can if desired be made up in quantities ahead of time at a considerable saving of both time and labor.

USE PAPER CAREFULLY TO AID WAR EFFORT

Wood pulp is a strategic material—transportation and manpower limitations reduce potential production, and many wartime uses for pulp and paper products increase the demand. A cord of pulpwood will make enough powder to fire two rounds in a 16 in. naval gun. Pulpwood is needed to make fiberboard containers to protect overseas shipments of food, munitions, and supplies, and to make rayon for parachutes and medical dressings for the sick and wounded. Printing paper, essential in peacetime, is vital to the prosecution of the war in numerous old and new uses.

All who order and use paper should ask the following questions: Is it necessary? Can lighter paper be used? Can a smaller size be used? Can the number of printed pieces be reduced? Is an excessive inventory on hand?

NAVY NEEDS CONSTRUCTION MEN

Skilled tradesmen are urgently needed for enlistment in class V-6, naval reserve, for service in the Navy construction battalions, or "Seabees" as they are more popularly known. These battalions are comprised principally of mechanics, riggers, carpenters, divers, electricians, welders, blacksmiths, drillers, stevedores, steel workers, wharf builders, special equipment operators, and other specialists who build advance and mobile bases all over the world.

Ratings for men from 17 to 50½ years old, up to and including chief petty officer, are available. All applicants must be interviewed by a civil engineer corps officer; information on when and where this officer may be contacted may be had at local Navy recruiting stations.

You Can Aid the War Effort and Save Money Too by Carefully Studying All

FUEL SAVING METHODS

C. W. Kimball, Consulting Engineer, Cites Several Cases of Fuel Conservation by Thorough Attention to Details

AT PRESENT, any reasonable changes in heating plant equipment or operating methods that result in fuel savings return even greater money and other value than in the past. We have finished writing reports covering four steam power and heating plants that were under our supervision last year; the results obtained by careful planning and supervision may be of interest to other fuel users.

Last winter was more severe than the average so the savings indicated cannot be attributed to a milder season; on the other hand, if the savings had been increased to correspond to the increase in degree days, the results noted would be considerably more favorable than indicated by the figures.

We were employed first to make reports on the plants, their equipment, their operation, and to make recommendations for possible changes to increase efficiency. After these reports were submitted, we were employed to carry out the work recommended and to follow the operation of the plants after the changes were completed to report on the results obtained.

Large YMCA Building Saves 139.5 Tons

A large YMCA building with two 72 in. diameter HRT boilers operating at 50 psi pressure burns coal, with one boiler hand fired and the other stoker fired. The pumps, return tanks, and one of the water heaters were worn out and required renewing. This condition prompted a careful survey of the whole plant.

After the survey and check of operating conditions, the changes recommended in equipment and operating methods included reducing the operating pressure to 10 psi, installation of new pumps and piping, overhauling all return traps, and cleaning the system.

The building was used even more fully last year than the previous one and no correction has been made for the more severe weather. In the corresponding four winter months before the changes, the plant used 416.9 tons of soft coal. During the same months after the changes, the plant used 277.4 tons of coal, a saving of 139.5 tons. The cost of the changes was less than $5000.

Manufacturing Plant Increases Boiler Capacity

A large manufacturing plant, on war work, reached the limit of its boiler plant capacity and asked for a report on the equipment, its capacity, and efficiency—with recommendations as to additions and changes to provide for future load increase and to improve operating conditions. This plant had six HRT

boilers, 135 hp each, with hand stokers burning soft coal. The boiler settings and supporting steel were in poor condition and three of the boilers were so old that replacement was imperative.

A careful study was made and definite recommendations were submitted for the plant development. They included the removal of the old boilers and the installation of three new water tube boilers, with stokers, in their place, using the present drums, piping, chimneys, and other equipment that was available.

The enlarged plant has operated since the first of December, has cared for the added steam demand developed, and has satisfactorily heated the factory during some of the coldest weather in recent years. The records kept at the plant show that approximately 40 per cent more steam was needed but that the coal consumption increased only 5 per cent, making no correction or adjustment for the unusually low temperatures experienced. As the old plant burned from 30 to 45 tons of coal per day, the savings due to the changes made the investment really worthwhile.

Building Converts to District Steam

Another plant served a large building and burned bunker C oil. The boiler installation was modern in every way and no changes in boiler or equipment appeared possible to save fuel; money was not available to change the boilers over to coal. The heating system includes unusually complete individual room automatic control, with day and night setting and each floor a separate unit. No changes in the heating or control system seemed practical or advisable from the steam saving point of view.

It was decided to purchase steam from the utility company in order to save oil, but with the thought that the cost of steam this way might exceed the cost of generating steam with the boiler plant, steps were taken to reduce the use of steam in every way possible. It was, therefore, decided to watch carefully all phases of the use of steam, shutting off the entire system when possible, reducing the heat in various rooms and departments, lowering the thermostat settings, and reducing as far as possible the ventilation throughout the building—in other words, to give careful attention to all small details.

A new use for the heat in the return water of condensation was developed and made possible without any new equipment or additional operating expense and a saving was made on this item.

The plant records show a saving in steam of approximately 35 per cent, this saving being made without the installation of any new equipment of any kind but simply by making the best use of present equipment, keeping a careful watch of all parts, and making full use of every pound of steam purchased. As this building used approximately 10,000,000 lb of steam per winter month during the preceding year, the saving indicated means that a substantial amount of fuel has been made available for others.

SUMMARY — It's often the little things that count but which are frequently overlooked. When it comes to saving fuel—highly important today not only to reduce costs but to contribute to the war effort—careful attention to operating details and the condition of the heating equipment will invariably lead to worthwhile results . . . That's the point Mr. Kimball—of Richard D. Kimball Co., engineers, and a member of the HPAC's board of consulting & contributing editors—makes here. The cases he cites suggest similar study of other heating installations.

Factory Boosts Operating Efficiency

A manufacturing plant having two 78 in. diameter by 20 ft 0 in. long HRT boilers set up 9 ft 0 in. from the floor, equipped with two high pressure mechanical oil burners using bunker C oil fuel, used approximately 1,400,000 gal of oil per year before the changes were made. The two boilers operated at 175 psi pressure with an output of 20 to 25,000 lb per hr of steam, 24 hr per day except on weekends and vacation periods.

These boilers were overloaded beyond their economical operating point and in case of breakdown or repairs no other steam was available.

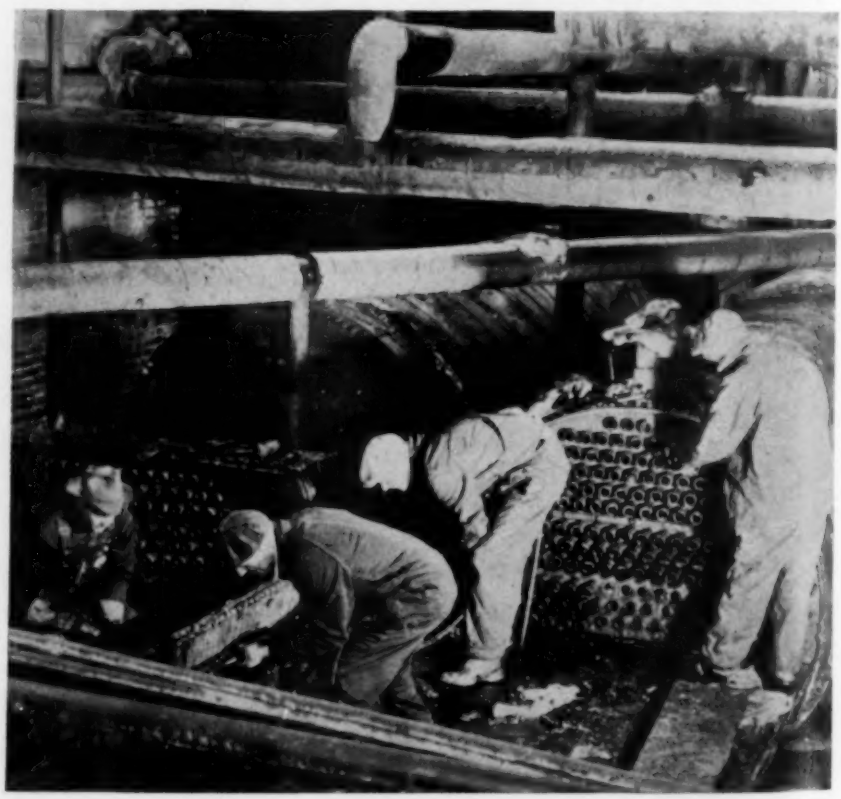
After a careful study and report a new water tube boiler was recommended. This was later installed in the same boiler room and connected with the existing pumps, heaters, piping, and controls. Improved feedwater treatment was also included, with minor changes in the piping and use of return water. The new boiler has now been in operation approximately one year and the records indicate that the operating efficiency has been improved 15.5 per cent. Based on a year's fuel consumption and at the present prices, the cost of the additions and changes will be returned within three years.

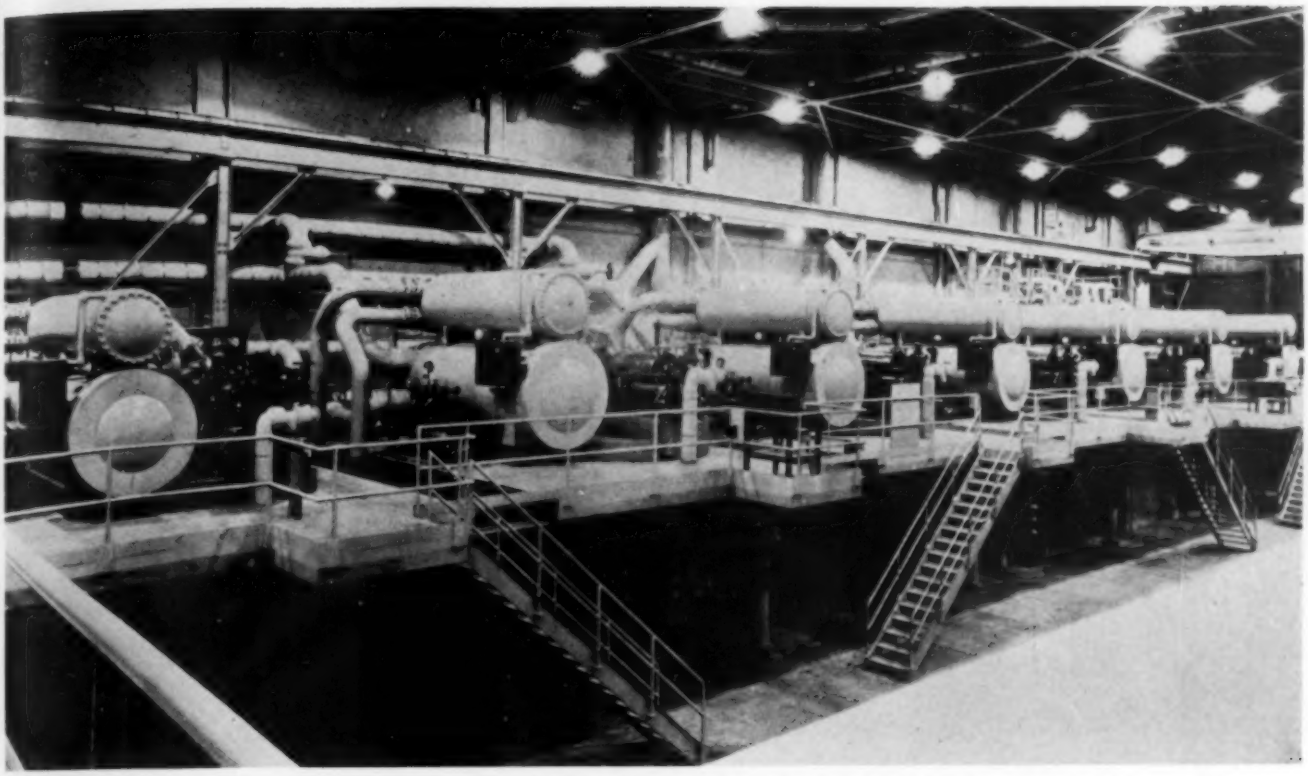
This new boiler is now to be changed to coal by installing an underfeed stoker in order to conserve oil. Comparable coal savings will of course continue to be made.

WHAT SHOULD PLANTS LOOK FOR IN THE WAY OF SCRAP?

Metal shavings; scraps after stamping out parts; broken machinery and parts; cable; old coolant pumps; line shafting; old drills and chucks; rejected pieces; old chain; oil drums; filings and grindings; bolts, nuts and rivets; plungers; pistons; saw blades; old wrenches; pipes and valves; old boilers; discarded equipment of any sort containing iron or steel.

Obsolete tar heat exchangers being relegated to the scrap heap at a Standard Oil refinery, to make bombs which will help make Hitler obsolete





Battery of seven refrigeration machines for air conditioning a windowless bomber plant

7000 TONS OF REFRIGERATION HELP TO MAKE IT HOT FOR HERR HITLER

ONE OF the nation's largest industrial air conditioning systems is in operation at a blackout bomber plant at Tulsa operated by Douglas. The equipment has a refrigerating capacity of 7000 tons.

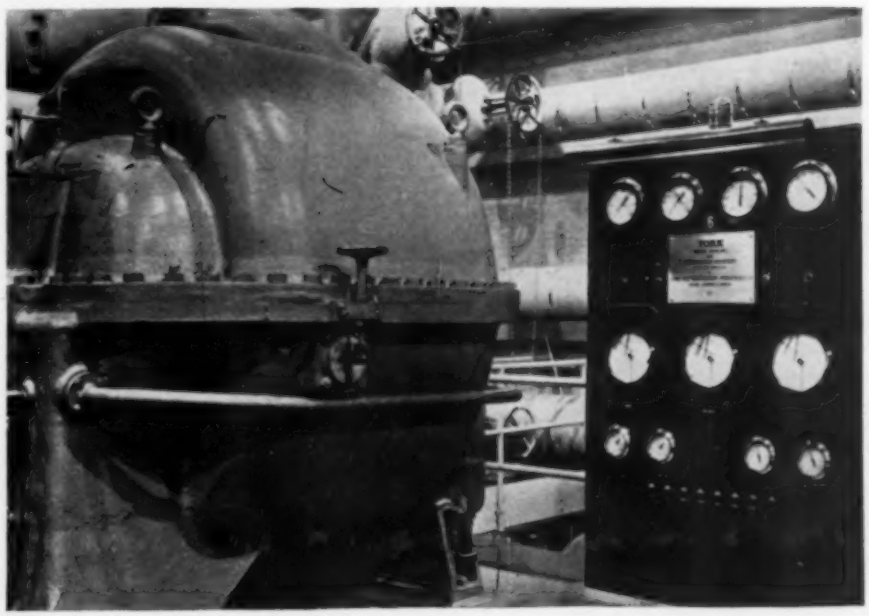
A battery of seven turbine driven centrifugal refrigeration machines chills more than 14,000 gpm of water from a temperature of 59 to 47 F. The chilled water is pumped through cooling coils situated in all parts of the building.

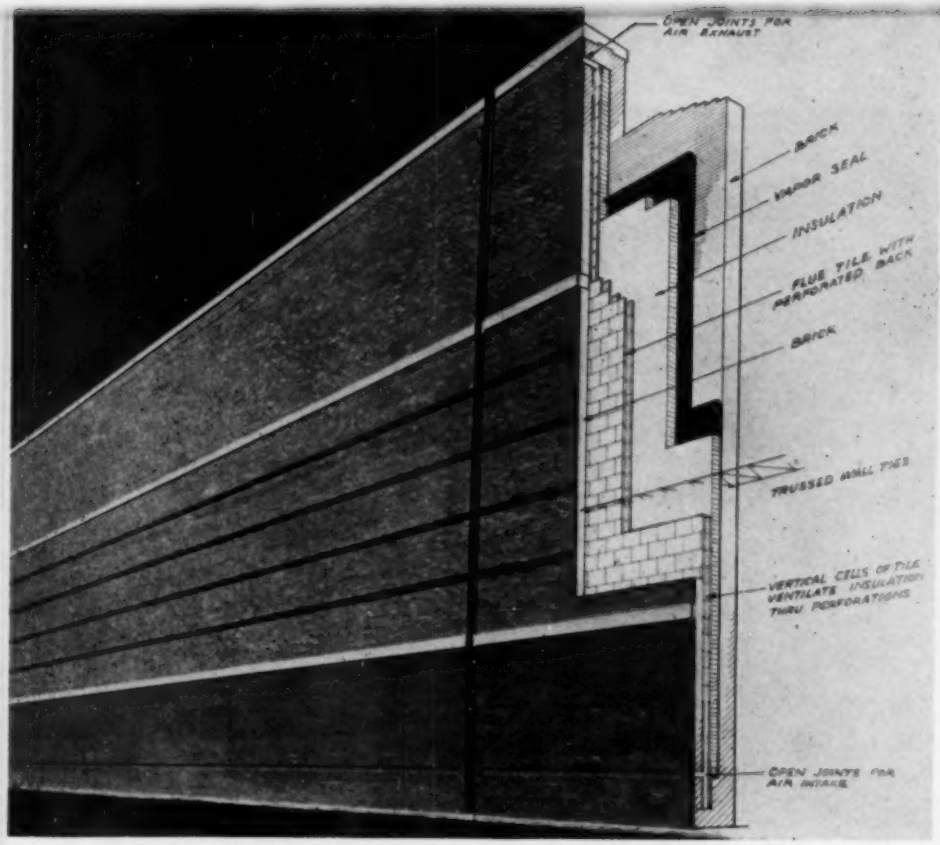
Air conditioning in the windowless blackout plant is vitally necessary to maintain normal operations during the summer and to a large extent in the winter as well. Outside summer temperatures at the plant location go as high as 100 F and average 80 F, but in the blackout plant the mercury would climb to an average of 110 F without air conditioning. Machinery, lighting, and the hundreds of workers themselves would all contribute to increasing the temperature to an unbearable level. On unusually warm days, operations might have to cease altogether.

A constant temperature of 80 F and a relative humidity of 50 per cent will be maintained by conditioning more than 3,000,000 cfm of air.

Approximately 110,000 lb per hr of steam is used by the seven turbines in the refrigeration plant to develop over 7000 hp needed to operate the compressors. The turbines work at 250 psi initial pressure and exhaust at 26 in. of vacuum. Each of six compressors has a refrigerating capacity of 1075 tons while a seventh has a capacity of 550 tons.—J. C. TWEEDELL, field manager, York Ice Machinery Corp.

These instruments enable proper operation of one of the huge refrigeration machines





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Open vertical joints in the two recessed courses of brick just about waist high and in a rowlock course just a foot below the limestone coping ventilate this wall, which has an insulating value equal to 80 in. of brick. This has been obtained by the use of ventilating tile with perforated back, a 4 in. mat of rock wool and a waterproof membrane vapor seal inside the wall. Reinforcing ties make it shatter resistant and keep the insulating wool permanently in place. The vertical break shown in this view is an expansion joint which is repeated at intervals along the length of the building

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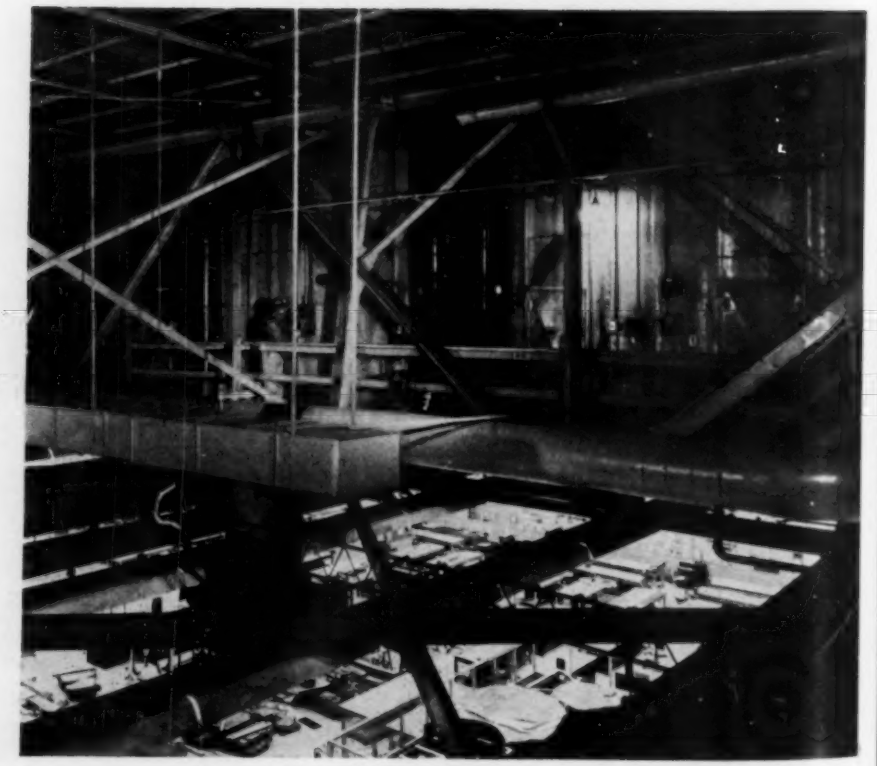
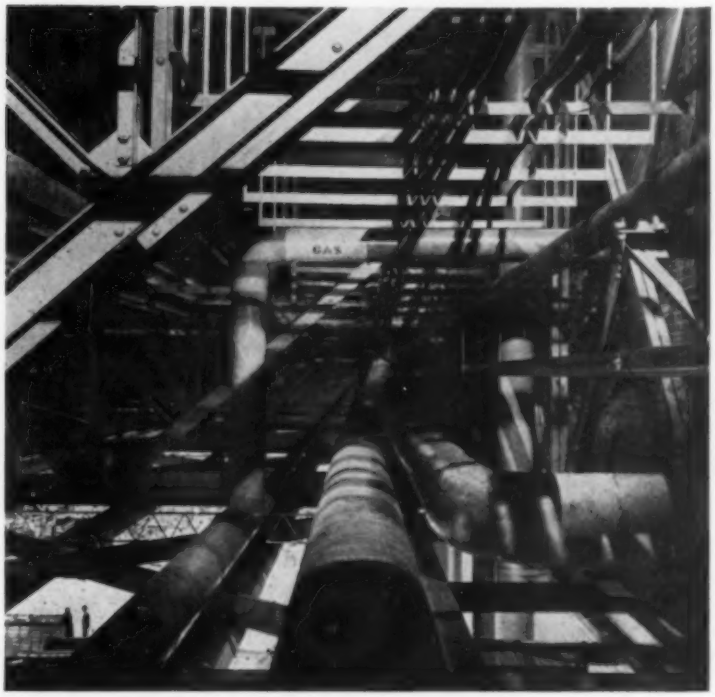
AIR CONDITIONED AIRCRAFT PLANT HAS WALLS THAT "BREATHE" SO AS TO AVOID CONDENSATION TROUBLES



Air conditioning units which serve this windowless plant are above the trusses on platforms similar to that shown here. They are readily accessible from catwalks extending the full length of the plant

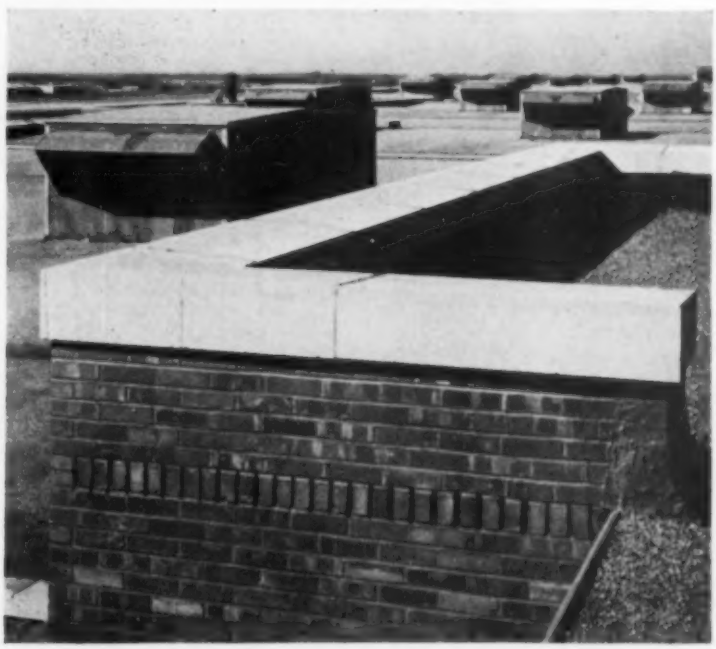


With all distribution systems concentrated in the trusses, the working area is entirely free of obstructions. This view, taken alongside the boiler house wall, shows two 18 in. chilled water lines which deliver cold water for use in cooling the assembly building. Directly above on the left is a line which carries pneumatic tubes and a 6 in. compressed air line is above it. A 10 in. gas feed line cuts over left to right above the others into the boiler room. The vertical pipe seen alongside the wall on the right serves as a sampling air duct which delivers outdoor air to the air conditioning control mechanism which automatically sets the controls for maintaining uniform atmospheric conditions within the plant. A concentration of pneumatic temperature regulation control tubes in the lower right corner cuts a sharp right angle into the boiler house, where the main operating control panel is situated

A LOOK behind the 17 million bricks in nearly two miles of "breathing windowless walls" enclosing Douglas Aircraft's new Oklahoma City plant would disclose "C-47 Sky Trains" coming off a complete production line where cattle grazed just a year before. The Austin Co. designed the plant and supervised construction.

When the engineers were asked to design the southwest's third huge heavy aircraft plant with the same controlled conditions provided in the first two, but with limited use of steel which made these possible, the idea of "breathing walls" of masonry was born. Instead of using fiber glass and steel, which gave side walls and roofs for the other plants a record insulating value, they designed a revolutionary brick wall over 50 ft in height which is ventilated through open vertical joints in one course near the top and in two courses waist high near the bottom of the outer brickwork.

Hollow ventilating tile serve as a flue through which air circulates vertically between the open joints. The tile has a perforated back which allows the 4 in. blanket of rock wool insulation to "breathe," thereby preventing condensation and keeping it permanently dry. The wool is held in place by lightweight trussed wall ties which hold the many layers of the wall together and make it shatter resistant. They are the only steel in the entire wall. While only a fraction as thick, the construction has the same insulating value as a solid 80 in. brick wall and is equal to the ferroglas construction, in which steel and fiber glass were combined at the other two plants. The new plant has a roof of the ferroglas construction.



This view from a point on the roof above the sliding door illustrates in detail the "breathing" wall construction. Open vertical joints in the rowlock course, seven below the limestone coping, form the upper end of the continuous ventilating flue through the walls. Open joints in two recessed courses waist high near the bottom of the structure provide the inlet, and circulation is obtained through vertical flue tile behind the facing brick. Nineteen penthouses above the low-roofed areas of the plant accommodate the upper section of air conditioning units throughout basic, primary and subassembly areas. They are enclosed with corrugated asbestos siding and have asbestos cement hoods over the louvers

Local boards start issuance of rations this month

How Rations for Fuel Oil Will Be Reissued by OPA

Policy on Conversion Also Announced

THE FUEL rationing division of the Office of Price Administration released on May 8 the following information on the reissuance of fuel oil rations and the conversion policy for next year:

Heat and hot water rations for 1943-44 will be, for most people, the same as the basic rations issued last fall. From the point of view of the industry, perhaps the most important improvement in the new fuel oil rationing program will be the issuance of rations well in advance of the beginning of the heating season. In PAW districts 1 and 2, the new rations for next winter will begin to reach consumers hands in June so that substantial deliveries may start by midsummer.

The reapplication of the great majority of heat and hot water consumers will be made on a one page form, R-1167, with consumer instructions on the back. The form will ask for the name and address of the applicant, the address of the premises to be heated, and the name and address of the person to whom the ration was issued last year. If the consumer simply signs his name, he will receive automatically the ration to which he is entitled under the regulations. He will also be given an opportunity to indicate voluntarily that he will accept a smaller amount than his basic ration of 1942-43.

The consumer will be asked to give the name and address of his principal supplier on a stub attached to the application form, together with the grade of product which he uses.

The general rule for ration determination means that a consumer will ordinarily receive the total allowable ration determined last fall or winter for the entire heating year 1942-43. The total allowable ration included the inventory declared by the consumer on his original application, but did not include, of course, auxiliary and supplemental rations issued during the winter for sickness or hardship. Where the local boards during the heating season made corrections in its calculations of the total allowable ration, the corrected figure will be the guide for the new ration. Where consumers during the heating season obtained a substitute ration because of change of circumstance (amendment 46) the total allowable ration figures on the new basis will be the guide.

Cases for which increases over last year's basic ration will be automatically given (unless the consumer voluntarily asks for less) include small houses, both with central heating plants and with space heating equipment. This small house adjustment will be made for only very small

houses in the northern part of the rationed area and will cover somewhat larger houses in the south. Automatic increases in rations will also be given to those who were affected by the area ceiling on very large houses last winter and to all private dwellings in the lower part of zone D.

No adjustments will be made under the new regulations for heat and hot water rations issued to buildings other than private dwellings.

Form R-1167 will be available only to consumers who reside at the same address as last winter or to members of their families. Consumers who have had a change of address or who may be entitled to larger rations because of various changes, such as an increased number of occupants, will apply at a later date on special forms prepared for those purposes.

In order to achieve the goal of substantial summer fillup, it is necessary for reapplication forms to be returned to the local boards at the earliest possible moment. The industry can greatly assist in achieving this goal by urging consumers to return their application forms promptly. It may be helpful to point out to the public in direct by mail and other consumer advertising some of the vital advantages of prompt compliance with this request, such as:

1) Greater efficiency in delivery operations, including the use of scarce manpower and scarce equipment, if deliveries can start well in advance of the heating season.

2) Greater assurance of supply for individual consumers if their tanks can be filled before the heating season starts.

3) Greater certainty of overall supply, adequacy for next winter, particularly on the east coast, if the industry can move products forward into consumers' tanks and use its own storage capacity fully for stock building before the heating season starts.

Reapplication Stub

The stub at the bottom of the reapplication form R-1167 is to be filled in by the applicant and the local board. The dealer's name and address, together with a check mark in the box opposite the type of fuel oil, is to be filled in by the consumer. The local board will fill in the classification of the consumer, and the amount of the ration.

This information will be most valuable in indicating to the supply and distribution committees not only next season's rationed demand by type of fuel oil and by area, but also the amount that will flow through each channel of distribution. Accurate information of this nature can be of great value in distributing the available supply during the coming heating year.

Ration Banking

Ration banking for consumers, dealers and suppliers will start July 1, 1943. The following groups will participate:

1) All primary suppliers.

2) All dealers whose gallonage of all fuel oils amounted to 250,000 gal, from June 1, 1942, to May 31, 1943.

3) All consumers both heating and nonheating, whose annual ration will exceed 50,000 gal.

4) In addition, any consumer whose annual ration is between 20,000 and 50,000 gal may, at his option, participate by securing a certificate from the local board instead of coupons.

A person eligible for a fuel oil bank account must open the account at the bank in which he now maintains a dollar checking account. If he has no dollar checking account, or if his bank does not participate in ration banking, he then may open the account at any bank which participates in ration banking. The bank will furnish ration checks, deposit slips, and signature cards to the depositor without charge. The expense of ration banking is borne by the government.

After a ration bank account is opened, a depositor must thereafter deposit all fuel oil ration credits he receives, and must make all remittances covering the transfer of fuel oil in the form of ration checks.

Only one ration bank account may be opened by any one consumer, unless undue hardship is incurred and permission is obtained from the Office of Price Administration in Washington, D. C., to open more than one account.

A dealer or supplier who operates more than one establishment may open one account for each establishment, or may have a single account cover all the establishments.

Some companies have asked whether they could have their own checks printed (using a rubber stamp for inserting the name of the bank) to avoid handling a number of different check books. Such an arrangement may be made if all OPA specifications are complied with.

Gummed Sheets

Gummed sheets for ration coupons will continue to be used instead of envelopes.

The industry advisory council was in full agreement that gummed sheets are more desirable. There have been a few requests that the use of gummed sheets or envelopes be made optional. For several reasons the optional feature seems undesirable. Some of these include the advantage of gummed sheets for ration banking, the reduced chances of errors and dishonesty, and the desirability of a uniform procedure for both gasoline and fuel oil.

With the issuance of the larger denomination coupons, for the new rations, the labor involved in pasting coupons on the gummed sheets will be greatly reduced.

Conversion Program for 1943-1944

The conversion policy committee has completed a thorough study of the various aspects of the conversion program. The committee is composed of representatives of the War Production Board, Office of Civilian Supply, Petroleum Administration for War, Solid Fuels Coordinator, Office of Defense Transportation, and the Office of Price Administration.

The following policy is to be made effective:

1) Continue the present policy of not requiring mandatory conversion of private dwellings.

2) Discontinue the present policy of denying auxiliary rations to convertible private dwellings.

3) Discontinue at once all government promotion by OWI, OPA, PAW, etc., urging the conversion of private dwellings to coal, with this decision to be reviewed on July 1 and September 1.

4) Continue the present OPA policy of mandatory conversions of heating equipment in buildings other than private dwellings, using oil for heating or hot water, but with the following exceptions:

a) No mandatory conversions of this type shall be made in Florida, Georgia, Washington, Oregon, and Idaho.

b) No mandatory conversions of this type shall be made for installations using less than 10,000 gal in the 1942-43 heating year in New

TO CONTINUE CONVERSION OF BUILDINGS OTHER THAN HOMES

HERE'S a quick summary of the policy on conversion from oil fuel for the coming heating season, as announced last month by OPA:

1) Continue present policy of mandatory conversions of heating equipment in buildings other than private dwellings, except in Florida, Georgia, Washington, Oregon, and Idaho, and except for buildings which used less than 10,000 gal of oil for the 1942-43 heating year in New England, North Dakota, South Dakota, Nebraska, Kansas, and Missouri only.

2) No mandatory conversions of private dwellings, even when auxiliary rations are requested.

England, North Dakota, South Dakota, Nebraska, Kansas, and Missouri.

5) Continue present PAW policy of virtual mandatory conversion of industry users of oil for power and processing, but with the following exceptions:

a) No mandatory conversions of this type shall be made in Florida, Georgia, Washington, Oregon, and Idaho.

b) No mandatory conversions of this type shall be made of installations using less than 10,000 gal in the 1942-43 heating year in New England, North Dakota, South Dakota, Nebraska, Kansas, and Missouri.

6) Continue present OPA policy of not requiring conversion of kerosene range burners.

EXTRA OIL RATIONS FOR HEATING WATER

Apartment houses, rooming houses, hotels and similar residential buildings using fuel oil for hot water purposes only are now eligible to receive extra rations if basic hot water needs have increased, the Office of Price Administration announced May 7.

Up to that date, adjustment of hot water allotments had not been permitted for these residential structures, defined as "residential premises other than private dwellings."

Previously (Amendment 45), OPA provided for similar adjustment of rations for apartment houses and similar residential buildings using oil for both heat and hot water. The May 7 action—contained in Amendment 62 to the fuel oil ration regulations (Ration Order 11)—extended this provision to consumers using oil only for hot water.

NEW FILE CARD DEVISED BY LOCAL BOARD SIMPLIFIES REISSUANCE OF OIL RATIONS

Summary of Essential Data Avoids Reference to Cumbersome, Bulky Files, Permits More Use of Volunteer Help, Says E. M. Mittendorff

THE FUEL section of the Office of Price Administration in Washington, D. C., recently sent to the local rationing boards a directive covering preliminary instructions regarding the issuance of fuel oil rations for the period from October 1, 1943, to September 30, 1944. Before these new rations are issued, it will be necessary to review and compile the data on all applications for which a ration was issued for the past heating season.

Mr. Mittendorff, engineer with the Sarco Co., is an OPA consultant on fuel oil rationing.

After that, each board has to address the envelopes and send the new application forms to each consumer.

These old files have become very cumbersome lately due to the issuance of auxiliary rations either on form 1104 or 1134 or because of change of occupancy or other reasons.

Two ladies, Mrs. Purdy and Mrs. Boettiger, members of the Glencoe, Ill., local rationing board gave this matter some thought—particularly with the idea to use more volunteer workers in this routine work of issuing the 1943-1944 rations on fuel oil. They have designed a filing card as shown here (actual size). After all the information about a particular oil consumer has been filled in, no further reference has to be made to the old, cumbersome files and any volunteer worker can address envelopes and forms to be sent to the oil consumers.

We believe that this form will be interesting to all local rationing boards and to all engineers in the ration areas.

NAME	ADDRESS	
1942-43 RATIONS		1943-44 RATIONS
Original (n)	BASIC—	Appl. Rec'd / Processed / Coup. Mailed
Adjustments due to changes in:	Auxiliary (1104)	BASIC RATION
Measurement	Hardship (1134)	BALLAST
Occupancy	Corrected Inventory	
Heat History	Ballast	COUPONS ISSUED
	Coupon Value Increase	
TOTAL: BASIC RATION _____		

WATER SPRAYED DIRECT EXPANSION COILS

• Their Theory and Characteristics •

Although Used Extensively in the Manufacture and the Testing of War Goods, the Fundamentals of Such Coils Have Never Before Been Analyzed as Completely as in This Treatment by William Goodman

OUR DISCUSSION of the theory and characteristics of water sprayed direct expansion coils is continued from the April and May issues of HPAC:

Increasing Capacity of Coil

Occasionally, after a sprayed coil is installed, an attempt is made to increase its capacity by increasing the quantity of air flowing over the coil. It is obvious that if the coil is operating at, say, 200 cfm per 100 sq ft in Fig. 7 (see p. 244, May HPAC), an increase to 400 cfm per 100 sq ft will result in a very material increase in the refrigerating capacity of the coil. The capacity will increase from 1.19 tons to 1.91 tons, or 60 per cent. On the other hand, if the coil is already operating at 400 cfm, an equal increase of 200 cfm to 600 cfm will result in a much smaller percentage increase in coil capacity. The increase will be from 1.91 tons to 2.34 tons, or an improvement of 22 per cent. Whether or not the capacity of a sprayed coil can be increased by increasing the quantity of air flowing through it depends entirely upon the quantity of air the coil is cooling before the change is made.

One point must be watched in connection with increasing the quantity of air flowing through a coil. In air conditioning systems, the air quantity flowing through the cooling coil cannot be increased indiscriminately if a given temperature and humidity is to be maintained in the conditioned room. To absorb a given quantity of heat and moisture in a room, a definite relationship must be maintained between the quantity of air supplied and the wet bulb temperature of the air supplied. This is discussed further in the following sections.

Air Quantity

The total quantity of air to be supplied to a conditioned space depends only upon the total internal heat gain of the room and the difference between the enthalpy of the supply air and the enthalpy of the air in the conditioned space. For example, if point *3* on the skeleton psychrometric chart of Fig. 8 represents the state of the air in the conditioned room and point *2* the state of the air leaving the sprayed coil and being supplied to the room, the amount of air to be supplied—for any one given internal total load in the room—will depend only upon the distance between points *2* and *3* [see p. 120 of the author's book, Air Conditioning Analysis]. The smaller the distance between points *2* and *3*, the greater will be the quantity of air that must be supplied to the conditioned space.

After point *2* has been selected, the weight of cold air that must be circulated can be computed from the following formula.

$$G = \frac{Q_t}{h_3 - h_2} \quad \ldots\ldots\ldots\ldots [9]$$

Cooling Cycle on the Psychrometric Chart

Before it is possible to discuss the selection of coils for any particular set of conditions, an understanding is essential of the complete cycle to which the air is subjected as it is cooled and dehumidified in the coil and then heated and humidified in the conditioned space. These cycles can best be illustrated on the psychrometric chart. After the cycles as they are illustrated on the psychrometric chart are understood, the various factors influencing the selection of coils can be comprehended more easily.

As has been shown [p. 120 of the book, Air Conditioning Analysis], to maintain the air in a conditioned room or refrigerated space at a definite temperature and relative humidity, the state of the air supplied to that room must lie somewhere along the moisture ratio line (also called the sensible heat percentage line) for that room. For example, on the skeleton psychrometric chart of Fig. 8, point *3* represents the state of the air to be maintained in the conditioned room. Line *3-5* represents the moisture ratio line for that room. The moisture ratio line is drawn at an angle which depends only upon the ratio of the total heat to the moisture which must be absorbed in the room to maintain state *3*. To maintain the air in the room in state *3*, the air leaving the cooling coils and delivered to the refrigerated space must be in

SUMMARY—Sprayed direct expansion coils are widely used in air conditioning and refrigeration work. Coils sprayed with water are used in air conditioning, and brine sprayed coils are, of course, used in low temperature air conditioning and refrigeration installations. Because such coils are used extensively today for all kinds of manufacturing and testing in connection with the war effort, a fundamental treatment of their theory and characteristics is especially timely. In spite of the fact that such coils have been used for many years, such a treatment has never before been published. . . . In the article of which this is the third part, the theory and characteristics of water sprayed coils are covered in a simple and thorough fashion with many illustrative examples to show not only how the characteristics of such coils are computed, but also to show the effect of variations in the various quantities which affect the performance. A thorough understanding of the basic characteristics and theory of sprayed coils should result in much more efficient and satisfactory installations. . . . Mr. Goodman is consulting engineer, the Trane Co., and a member of HPAC's board of consulting & contributing editors.

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some state which can be represented by a point like *2* along the moisture ratio line *3-5*.

As has previously been shown, when air is cooled by a sprayed coil, the change in the condition of the air takes place along the *condition line*—the line drawn on the psychrometric chart between the point representing the state of the entering air and the point on the saturation curve representing the temperature of the spray water. If all recirculated air (that is, no outdoor air) were supplied, the air would enter the sprayed coil in the condition represented by point *3* and be cooled to some point like *2* along line *3-5*. Point *5* would, of course, represent the required temperature of the spray water. In this case, the moisture ratio line for the room and the condition line would coincide.

On the other hand, if a part of the air supply came from the outdoors and only the remainder were recirculated from the room, the air entering the sprayed coil would consist of a mixture of return and outdoor air. In this case if point *4* of Fig. 8 represents the outdoor air and point *3* the return air, the state of the mixture entering the sprayed coil would be represented by a point like *1* on line *3-4* [see p. 107, Air Conditioning Analysis]. Consequently, in Fig. 8 where point *1* represents the condition of the air entering the sprayed coil and point *2* represents the required condition of the air leaving the sprayed coil, point *6* on the saturation curve represents the temperature at which the spray water must operate if air in the state represented by point *2* is to be obtained from the coil. Point *2* must, of course, always lie at the intersection of lines *1-6* and *3-5*.

Summarizing, air entering the sprayed coil in the state represented by point *1* is cooled to state *2* in which condition it is then delivered to the room where it absorbs heat and moisture as its state changes from point *2* to point *3*. Air in state *3* is withdrawn from the room and mixed with outdoor air in state *4* resulting in a mixture represented by state *1*; this mixture is then drawn through the sprayed coil and the entire cycle repeated.

Effect of Outdoor Air on Cooling Cycle

In determining the effect of outdoor air on the cooling cycle, two separate cases must be considered because the quantity of outdoor air to be supplied is commonly determined by one of two different methods. In the first case, the quantity of outdoor air to be supplied is specified as a *constant percentage* of the total air that is to be circulated. In the second case, the *volume* of outdoor air to be supplied is specified.

In the first case in which a constant percentage is specified, the location of point *1* along line *3-4* of Fig. 8 would remain fixed in position, and would depend only upon the specified percentage. The distance *3-1* would bear the same proportion to the distance *3-4* as the percentage of outdoor air would bear to the total. In other words, if the outdoor air is specified as 35 per cent of the total air circulated, then the distance *3-1* would be 35 per cent of the distance *3-4*.

As long as point *1* remains fixed in position, it is obvious that the various condition lines representing the cooling of the air in the spray chamber will all originate at point *1* as shown by the dotted line and by the solid line *1-2* of Fig. 8. The temperature of the spray water is read at point *6* where condition line *1-2* intersects the saturation curve. The dotted line of Fig. 8 shows a condition line for which the spray water is at a higher temperature than for line *1-2*. For cooling along the dotted line, the required final temperature of the air and the temperature of the spray water both lie closer to point *5* than they do for line *1-2*.

For the second case in which the volume of outdoor air is to be held constant, the percentage of outdoor air in the mixture will change with every change in the location of point *2* of Fig. 9. As point *2* moves closer to point *5*, it is obvious that the weight of air to be circulated will decrease. However, inasmuch as the volume of outdoor air is to be held constant, the *percentage* of outdoor air in the mixture will consequently increase. If the percentage of outdoor air in the mixture increases, point *1* must move up closer to point *4* in Fig. 9. Hence, it is apparent that the location of point *1*—which represents the condition of the air entering the spray cooler—will change with the location of point *2*.

If a lower final air temperature is selected along line *3-5* than the one represented by point *2*, the new condition line will appear like the upper dotted line in Fig. 9. In this case also, as point *2* moves down toward point *5*, the temperature of the spray

Fig. 8—Diagrammatic illustration on skeleton psychrometric chart of air conditioning cycle for a constant *percentage* of outdoor air

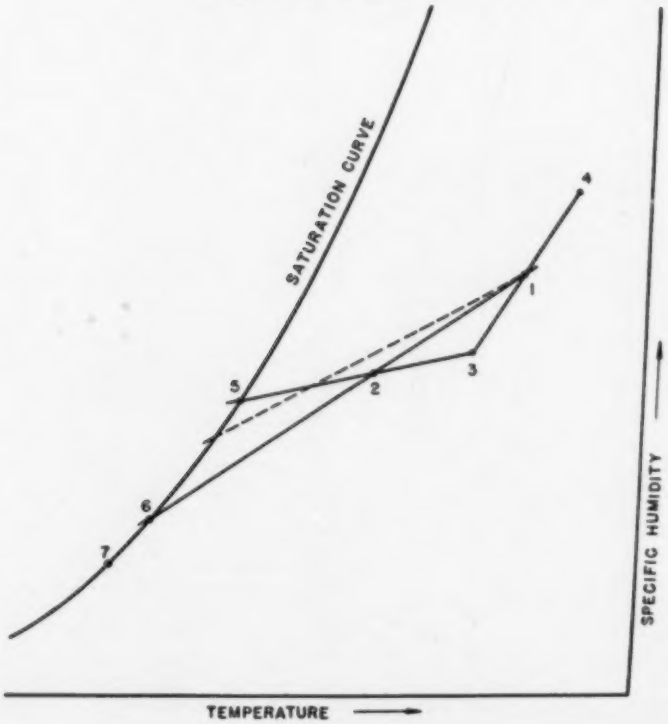
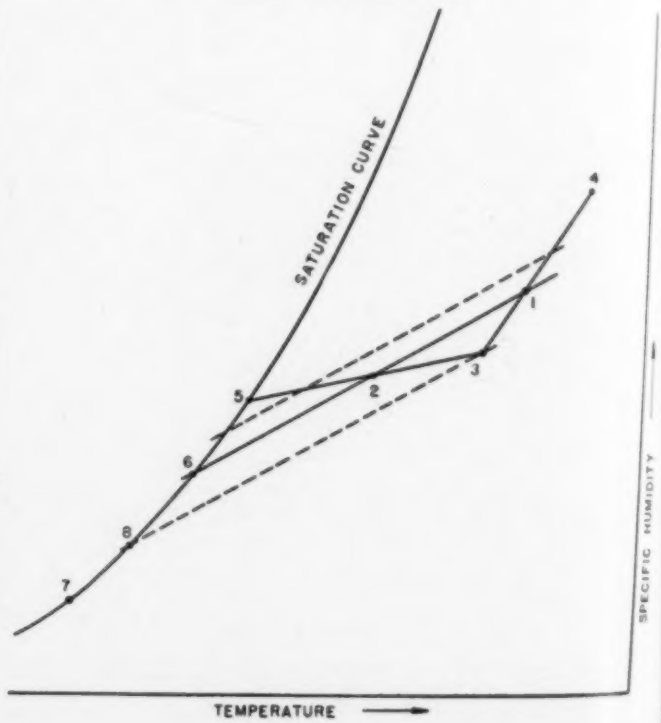


Fig. 9—Diagrammatic illustration on skeleton psychrometric chart of air conditioning cycle for a constant *volume* of outdoor air



water moves up toward point *5*. Notice that this new dotted condition line is parallel to condition line *1-6*. All of the condition lines through the various final temperatures along line *3-5* will be parallel to each other. This fact is proven in the footnote* below.

In both Figs. 8 and 9, the highest spray water temperature which can theoretically be used is, of course, the temperature represented by point *5*. Any spray water temperature higher than this would result in the failure of lines *1-6* and *3-5* to intersect to the right of the saturation curve. In other words, point *2* representing the intersection of these two lines should lie on line *3-5* to the right of the saturation curve. Although a point of intersection to the left of the saturation curve can theoretically be used, such a point of intersection is impractical because fogged air would be needed to satisfy the conditions of the problem.

In Fig. 8 the value of the theoretical minimum possible spray water temperature is obtained at the point where line *1-6* is tangent to the saturation curve. This is true providing the lowest refrigerant temperature is not fixed. If the lowest refrigerant temperature is fixed at a temperature higher than that at the point of tangency, then, of course, the lowest theoretical spray water temperature is equal to the refrigerant temperature.

There is also a theoretical minimum spray water temperature for the case illustrated in Fig. 9. This minimum spray water temperature is obtained by drawing through point *3* of Fig. 9 a condition line parallel to the other condition lines like *1-6*. The minimum spray water temperature is then read at point *8* where the dotted line through point *3* intersects the saturation curve.

Refrigerating Capacity

If no outdoor air is supplied to the conditioned room, the refrigerating capacity required will depend only upon the total internal heat gain of the conditioned space. In this case the refrigerating capacity will be constant and independent of the temperature of the air supplied to the conditioned room; that is, the refrigerating capacity will be independent of the location of point *2* along line *3-5* of Fig. 8.

In selecting sprayed coils, it is necessary to consider the effect of the weight of outdoor air supplied on the refrigerating capacity for which the sprayed coil is to be designed. The total refrigerating capacity required is the sum of two separate parts: The first part depends only upon the total internal heat gain of the room. The second part depends only upon the heat which must be removed to reduce the enthalpy of the outdoor air down to the enthalpy of the *room* air. In other words, the additional refrigerating capacity required for the outdoor air depends only upon the heat removed in cooling the outdoor air from point *4* to point *3* of Fig. 8 [see p. 158, Air Conditioning Analysis]. The refrigerating capacity required to offset the total internal heat gains of the room is constant at all times and independent of the amount of outdoor air supplied just as it would be if no outdoor air at all were used. The second part due to the outdoor air can either vary or be constant depending upon how the quantity of outdoor air to be supplied is determined.

As stated in the preceding section, the quantity of outdoor air to be supplied is commonly determined by one of two methods: In the first case, the quantity of outdoor air to be supplied is specified as a constant *percentage* of the total air that is to be circu-

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*On the psychrometric chart, the slope [see p. 55 of the author's book, Air Conditioning Analysis] of condition line *1-2* is

$$q = \frac{h_1 - h_2}{w_1 - w_2} \quad \text{.....[a]}$$

$$= \frac{(h_1 - h_3) + (h_3 - h_2)}{(w_1 - w_3) + (w_3 - w_2)} \quad \text{...[b]}$$

According to equation 9,

$$Q_i/G = h_3 - h_2 \quad \text{.....[c]}$$

Similarly,

$$W_i/G = w_3 - w_2 \quad \text{.....[d]}$$

It can be shown that [p. 159, Air Conditioning Analysis],

$$Q_o/G = h_1 - h_3 \quad \text{.....[e]}$$

And,

$$W_o/G = w_1 - w_3 \quad \text{.....[f]}$$

Substituting equations (c) to (f) inclusive into (b),

$$q = \frac{Q_o + Q_i}{W_o + W_i} \quad \text{.....[g]}$$

The quantities Q_i and W_i are constant. The quantities Q_o and W_o are also constant [pp. 159-160, Air Conditioning Analysis] because

$$Q_o = G_o (h_4 - h_3) \quad \text{.....[h]}$$

and

$$W_o = G_o (w_4 - w_3) \quad \text{.....[i]}$$

Inasmuch as all the quantities in the righthand member of equation (g) are constant, the slope of line *1-2* of Fig. 9 is constant regardless of the location of point *2* along line *3-5* of Fig. 9.

Symbols

A = area, sq ft;
c = 0.24, specific heat of air;
f_g = coefficient of heat transfer between air and water (through air film), Btu per hr per deg per sq ft;
f_R = coefficient of heat transfer between wall of metal tube and evaporating refrigerant (refrigerant film coefficient), Btu per hr per deg per sq ft;
f_w = coefficient of heat transfer between water and metal wall of tube (water film coefficient), Btu per hr per deg per sq ft;
G = weight of dry air through coil, lb per hr;
G_o = weight of outdoor air supplied to conditioned space, lb per hr;
h_1 = initial enthalpy (total heat content) of air entering sprayed coil, Btu per lb of dry air;
h_2 = final enthalpy (total heat content) of air leaving sprayed coil, Btu per lb of dry air;
h_3 = enthalpy (total heat content) of room air, Btu per lb of dry air;
h_4 = enthalpy (total heat content) of outdoor air, Btu per lb of dry air;
h_w = enthalpy (total heat content) of saturated air at a temperature equal to the temperature of the spray water, Btu per lb of dry air;
M = a quantity defined by equation 2;
Q = total quantity of heat removed from the air, Btu per hr;
Q_i = total internal heat gain of conditioned space (equals sum of sensible and latent heat gains), Btu per hr;
Q_o = heat removed in cooling outdoor air to room condition, Btu per hr;
q = slope of line on psychrometric chart;
R = ratio of external to internal surface of coil;
t_R = temperature of refrigerant, F;
t_w = temperature of spray water, F;
t'_1 = initial wet bulb temperature of air F;
t'_2 = final wet bulb temperature of air F;
U = overall coefficient of heat transfer from spray water to evaporating refrigerant, Btu per hr per deg per sq ft (defined by equation 4);
W_i = moisture gain of conditioned room, lb per hr;
W_o = moisture removed from outdoor air in dehumidifying it down to room condition, lb per hr;
w_1 = initial specific humidity of air entering sprayed coil, lb per lb of dry air;
w_2 = final specific humidity of air leaving sprayed coil, lb per lb of dry air;
w_3 = specific humidity of air in conditioned room, lb per lb of dry air;
w_4 = specific humidity of outdoor air, lb per lb of dry air;
w_w = specific humidity of saturated air at a temperature equal to the temperature of the spray water, lb per lb of dry air;
Z = a quantity that depends on M (see Table 1).

lated. In the second case the *volume* of outdoor air to be supplied is specified.

In the first case, in which a constant percentage is specified, the refrigerating capacity required to cool the outdoor air will vary with the total weight of air circulated. Suppose in Fig. 8 that a mixture of return air in state *3* and outdoor air in state *4* enters a sprayed coil. The state of the mixture will be represented by point *1*. Obviously the air entering the sprayed coil in the condition represented by point *1* must be cooled to point *2* if the air in the room is to be maintained in the state represented by point *3*.

As is apparent from equation 9, the total quantity of air which must be circulated depends only upon the distance between points *2* and *3* and the total internal heat gain of the conditioned room. Inasmuch as the outdoor air in the mixture is a constant percentage of the total quantity that must be circulated, the weight of outdoor air supplied will also vary with the location of point *2* along line *3-5*. Consequently, as long as points *4* and *3* are constant, the portion of the refrigerating capacity required to cool the outdoor air will vary with the location of point *2* along line *3-5* of Fig. 8. The smaller the distance between points *2* and *3*, the greater will be the total quantity of air that must be supplied and the greater will be the refrigerating capacity required to cool the outdoor air. Hence, because the refrigerating capacity required for the internal heat gain of the room is constant, the smaller the distance between points *2* and *3*, the greater will be the total refrigerating capacity required. Conversely, the greater the distance between points *2* and *3*—that is, the smaller the distance between points *2* and *5* — the smaller will be the weight of air that must be circulated and the smaller will be the required total refrigerating capacity.

In the second case in which a constant volume is specified, the part of the refrigerating capacity required to cool the outdoor air is constant and independent of the total weight of air to be circulated. Consequently, the total refrigerating capacity is also constant and independent of the weight of air to be circulated. In other words, the required total refrigerating capacity is independent of the location of point *2* along line *3-5* of Fig. 9.

Selecting Coil for a Constant Percentage of Outdoor Air

Only the case in which the percentage of outdoor air to be supplied is constant will be discussed in this section. In the sections which follow, the discussion will cover the case in which the quantity of outdoor air is constant; and the case in which no outdoor air is supplied, only recirculated air being used.

When selecting a coil for a definite application, it is desirable, if possible, not to fix the temperature of the refrigerant in advance. Instead, either the temperature of the spray water or the temperature to which the air is to be chilled should be selected first. Which of the two is chosen first is immaterial. The case in which a coil must be selected for a given refrigerant temperature is discussed later.

To select a coil, point *1* is located along line *3-4* of Fig. 8. The location of point *1*, of course, depends upon the constant percentage of outdoor air to be supplied. Next, point *6* representing the temperature of the spray water can be chosen at some value which lies below point *5*. A line drawn from point *1* to point *6* intersects the moisture ratio line *3-5* at point *2*, which represents the final condition to which the air should be chilled for the selected spray water temperature.

After first selecting either the spray water temperature or the final air temperature, the total weight of air to be circulated to the conditioned room can be computed by means of equation 9. After the weight of air has been determined, the required refrigerating capacity of the coil can be figured from the fact that the air is to be cooled by the sprayed coil from point *1* to point *2* of Fig. 9. The ratio Q/G can now be figured. Knowing the ratio Q/G and the quantity $(h_1 - h_w)$, equation 1 [p. 166, April HPAC] can be used to solve for Z. (h_1 is, of course, the enthalpy at point *1* and h_w is the enthalpy of saturated air at the temperature represented by point *6* of Figs. 8 and 9.) The value of M corresponding to the computed value of Z can then be found in Table 3, p. 245, May HPAC. From this value of M, the value of A/G, the surface area required per pound of air, can be found by means of equation 2, p. 166, April HPAC. Once Q/G and A/G have been determined, the ratio Q/A can be found after which the value of t_R, the required refrigerant temperature, can be found by means of equation 3, p. 167, April HPAC. The following example illustrates the method of selecting a sprayed coil for a constant percentage of outdoor air.

Example 5—The air in a conditioned room is to be maintained at 80 F dry bulb and 67 F wet bulb (point *3* of Fig. 8). The total internal heat gain of the room (sensible plus latent) is 12,000 Btu per hr, or 1 ton. The ratio of the total heat gain to the moisture gain in the room is such that the moisture ratio line *3-5* of Fig. 8 intersects the saturation curve for a 29.92 in. barometer at a temperature of 57 F (point *5*).

The outdoor air is at 95 F dry bulb and 75 F wet bulb (point *4*). The quantity of outdoor air to be supplied is to be 35 per cent of the total air circulated to the conditioned space.

Assume that the temperature of the spray water is to be 54 F, and that $f_s = 10$ and $U = 25$. Find: (a) The wet bulb temperature of the air supply. (b) The volume of standard air that must be supplied. (c) The total load on the coil. (d) The area of surface required. (e) The temperature of the boiling refrigerant.

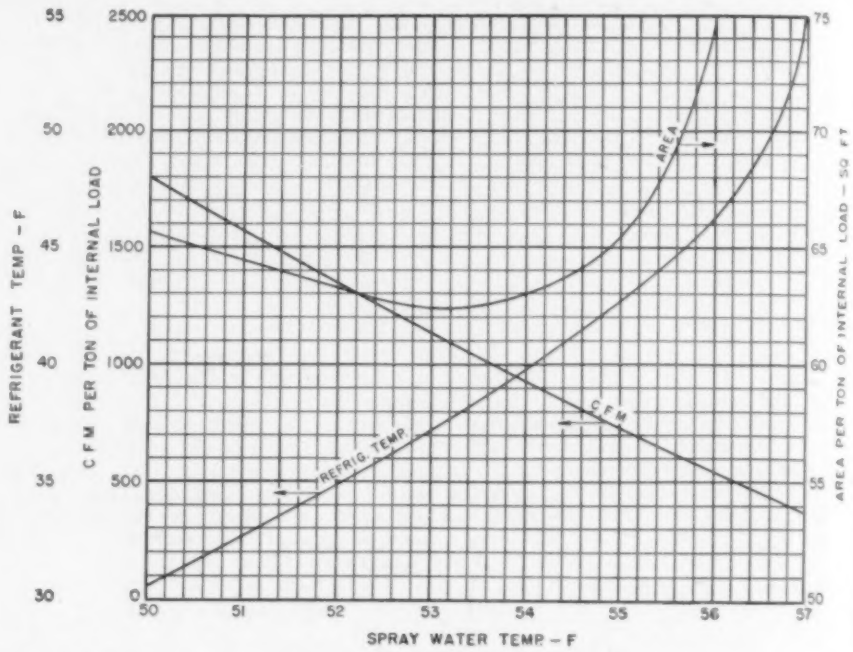


Fig. 10—Characteristic curves for an installation in which *percentage* of outdoor air is to be constant

Solution

a) On line *3-4* of Fig. 8, so locate point *1* that the distance *1-3* is 35 per cent of the distance *3-4*. Point *1*, therefore, represents the constant initial condition of the air entering the coil. Next draw the moisture ratio line *3-5*. Then locate point *6* where the vertical line of temperature for

54 F intersects the saturation curve of 29.92 in. Next draw line *1-6*. Locate point *2* at the intersection of lines *1-6* and *3-5*. The wet bulb temperature of the air to be supplied to the conditioned room is 63.2 F as read at point *2*.

b) From Table 5 [p. 247, May HPAC] for $t'_1 = 67$ F, $h_3 = 41.57$ Btu, and for $t'_2 = 63.2$ F, $h_2 = 38.68$ Btu. Using equation 9,

$$G = \frac{12{,}000}{41.57 - 38.68}$$

$= 4150$ lb of air per hr per ton of internal load.

$$\text{Air volume} = \frac{4150}{60 \times 0.075}$$

$= 922$ cfm per ton of internal load.

c) The total heat which must be removed by the coil is the heat removed in cooling 4150 lb of air from point *1* to point *2*. For $t'_1 = 70$ F, $h_1 = 44.03$ and for $t'_2 = 63.2$ F, $h_2 = 38.68$.

$Q = 4150\ (44.03 - 38.68)$
$= 22{,}200$ Btu per hr.
$= 1.85$ tons per ton of internal load.

d) $\frac{Q}{G} = \frac{22{,}200}{4150}$
$= 5.35$ Btu per lb of air circulated.

For $t_w = 54$ F, $h_w = 32.58$ Btu, using equation 1 [p. 166, April HPAC],

$$Z = \frac{5.35}{(44.03 - 32.58)} = 0.467$$

Referring to Table 3 [p. 245, May HPAC] for $Z = 0.467$, $M = 0.629$.

Using equation 2 [p. 166, April HPAC],

$$\frac{10}{0.24} \times \frac{A}{G} = 0.629$$

or

$$\frac{A}{G} = 0.629 \times \frac{0.24}{10}$$

$= 0.0151$ sq ft per lb of air per hr.
$A = 0.0151 \times 4150$
$= 62.7$ sq ft per ton of internal load.

e) To determine the refrigerant temperature, first find Q/A by dividing Q/G by A/G,

$$\frac{Q}{A} = \frac{5.35}{0.0151}$$

$= 354$ Btu per hr per sq ft of surface.

From equation 3 [p. 167, April HPAC],

$$t_s = t_w - \frac{1}{U}\frac{Q}{A}$$

$$= 54 - \frac{1}{25} \times 354$$

$= 54 - 14.2$
$= 39.8$ F, required refrigerant temperature.

Example 5 was solved on the basis of 1 ton of internal load. The method of solving the problem would be exactly the same regardless of the magnitude of the internal load. The area and cfm required for an internal load of any magnitude can, of course, be obtained by multiplying the quantities per ton by the actual internal load. The area and cfm expressed on the basis of internal load are of interest because the internal load is constant for any one given set of conditions. Consequently the variation in the air quantity and area with different assumed spray water temperatures can be seen quite clearly when these quantities are calculated on the basis of 1 ton of internal load.

Notice in example 5 that the actual values of Q and G are not required, but only the ratio Q/G. The value of Q/G can be figured directly from the following obvious equation.

$$\frac{Q}{G} = h_1 - h_2 \quad \ldots\ldots\ldots\ldots [10]$$

The use of equation 10 is somewhat shorter than the method used in example 5. However, the method used in example 5 was adopted because it shows more clearly the effect of the spray water temperature on the total load on the coil and the air quantity required.

Suppose in example 5 that the individual values of Q and G had not been found, but only the value of the ratio Q/G had been determined directly by means of equation 10. Example 5 could then have been solved by first finding the ratio of the internal load to the total load, that is the ratio of Q/Q_1. The value of Q/Q_1 can be found from the following formula obtained by dividing equation 10 by equation 9.

$$\frac{Q}{Q_1} = \frac{h_1 - h_2}{h_3 - h_2} \quad \ldots\ldots\ldots\ldots [11]$$

The values of G/Q and A/Q were obtained in example 5. Multiplying these values by Q/Q_1 would have given directly the values of A/Q_1 and G/Q_1 required.

Note that the *internal* load is always less than the *total* refrigerating capacity of the sprayed coil if outdoor air is used. For instance, in example 5 the internal load was 1 ton whereas the total load on the coil is 1.85 tons.

For any particular example, it is of interest to assume a series of spray water temperatures and determine the variation in cfm per internal ton and the surface required per internal ton. This was done for the conditions of example 5 and the results are plotted in Fig. 10. This figure shows that the cfm per internal ton decreases as the spray water temperature is increased. This decrease is to be expected because as point *6* of Fig. 8 moves up toward *5*, point *2* also moves down toward *5*, thus increasing the spread between points *2* and *3* and decreasing the quantity of air required.

The most important fact illustrated by Fig. 10 is that the area per internal ton shows a definite minimum at one spray water temperature. In Fig. 10 this minimum occurs at a spray water temperature of about 53.2 F for which the area required per internal ton is 62.3 sq ft. The refrigerant temperature corresponding to this minimum area is 37.7 F.

Occasionally the refrigerant temperature required for the minimum area may be too low or the quantity of air to be circulated may be too great. The latter is the case for Fig. 10 where the air volume corresponding to the minimum area is almost 1100 cfm per ton of internal load. This is larger than the air volumes usually provided. In this case it would be necessary to compromise between a smaller air volume and a greater area. The air volume can be decreased considerably with only a relatively small increase in area. For example, if instead of selecting a spray water temperature of 53.2 F, a spray water temperature of 55 F is selected, the required air quantity will fall from 1100 cfm to 740 cfm, whereas the required area will increase only from 62.3 sq ft to 65.5 sq ft. If the spray water temperature is raised to 55.5 F, the air quantity will drop to 640 cfm and the required area will increase to 69 sq ft. In selecting coils and air quantities for installations using sprayed coils, compromises must frequently be made to achieve a satisfactory balance between area, air quantity, and refrigerant temperature.

The reason that a point of minimum area occurs in Fig. 10 can be explained as follows: As the spray water temperature is lowered, that is as point *6* of Fig. 8 moves down, the surface required decreases. The reason for this is that the distance between points *2* and *6* increases. On the other hand, as point *6* moves down, point *2* moves closer to point *3*. This means that the quantity of air which must be circulated increases. Inasmuch as the weight of outdoor air to be supplied is a constant percentage of the weight circulated, the refrigerating capacity required for the outdoor air continually increases as point *2* approaches point *3*, or as point *6* moves downward. As previously stated, as point *6* moves down, the required area tends to decrease because of the separation of points *2* and *6*. Eventually, however, the increase in area due to the increasing refrigerating capacity more than offsets the decrease in area due to the separation of points *2* and *6*. Hence, as point *6* moves downward, the area will pass through a minimum and will increase again because of the rapid increase in total refrigerating capacity required.

A HISTORY OF PIPING

M. A. Hasselmann Briefly Surveys Beginnings of Man's "Greatest Transportation System"

SUMMARY — It's always interesting to review the beginnings of an art as important to mankind as is piping. In this, the second of a group of articles scheduled for publication in HPAC, Mr. Hasselmann — of Tube Turns, Inc. — continues his review of the early development of our "greatest transportation system."

Reproduction of an old pen and ink drawing of the Pont du Gard in southern France. It represents the later, more artistic construction of the famous Roman aqueducts. The water channel runs along the top tier of arches; the lower tier is the bridge for the famous old Roman road in that area

CARTHAGE WAS founded in 850 B. C. in what is now Tunisia, where American soldiers and their allies fought the remnants of the axis' "Afrika corps." One of the remains of this ancient city will be familiar to every American soldier that returns from that area—the municipal reservoir, which consisted of 18 separate sections, each 100 ft long, 20 ft wide and 20 ft high, including a vaulted roof. This reservoir was so well constructed that it exists today in a remarkable state of preservation, though used for 2300 years and more for everything from holding water to housing donkeys. Every worthwhile Carthagenian residence had its own cistern and this large reservoir, to which was conducted rain water from a nearby slope, was supplementary.

Stone Piping

Another landmark is a huge aqueduct built by the Romans. Carthage was a powerful military and economic competitor that constantly threatened the Romans but the Romans eventually won the final playoff, held at Carthage about 150 B. C. Their soldiers were told to pillage the city and lay it flat. Many years later the Romans rebuilt Carthage as a colony and installed an excellent water system. The aqueduct, 60 miles long, brought spring water from the distant mountains.

Some of the distributing mains the Romans laid down were stone piping with a bore of 2 in., a groove at one end and an extending lip on the other. The lips fitted tightly into the grooves, maintaining position and minimizing leakage.

The First Roman Aqueduct

The first Roman aqueduct, completed 312 B. C., was built at public expense and the munificence of individuals. It delivered its water to three terminals or reservoirs, which were placed at different elevations. The highest supplied water to the homes of the wealthy, the middle to the fountains and, later, to public baths, and the lowest to the public water basins. Why, the records do not tell us, but probably the homes of the wealthy were highest-up on the famous hills of Rome.

The Rome of that time was comparable to the New York City of the 1830's—lusty, dusty, extremely busy, intoxicated with its growing power. A very active rich class, the patricians, directed its thriving industry and commerce, its republican government, and its military establishments. It was a city of predominantly wooden buildings and was just then getting its first paved streets. The main sewer was an open ditch that drained

downtown Rome and the nearby cattle market.

Bronze and Silver Piping

Pergamum, in Asia Minor, was so well built that many of its water mains were of bronze piping. Bronze piping that led into its famous library would hold water today.

The only known ancient water system that would hold water under considerable pressure was at Pergamum, built about 180 B. C. by a king to supply his palace. The water was conducted from a mountain for several miles over a course that varied in elevation above sea level by approximately 200 ft, and the piping had to contain a pressure of 16 to 20 atmospheres. The pipes were probably bronze and were covered by stones, cut to fit around the pipe. The stones remain, though the metal was salvaged in the intervening centuries; how the pipes were formed and joined cannot therefore be determined. Possibly to outdo Pergamum, a rich Roman later had silver water piping installed in his villa near Rome.

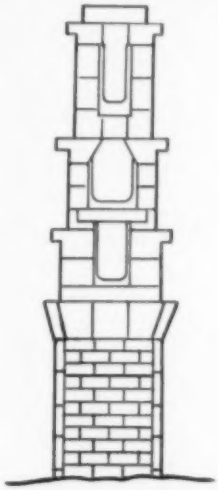
A Nation of Bathers

In the century preceding Christ the Romans began the building of their famous public bathing establishments, eventually having so many and such inexpensive ones that everyone could enjoy the luxury daily. Some of these baths were magnificent structures.

The baths of the emperor Diocletian accommodated 3200 bathers. There was a huge cold water swimming pool and a large hot water bath surrounded by acres of rooms and gymnasium facilities for every kind of play and sport. The baths of Caracalla (nickname for another emperor) occupied an area approximately the same as that now occupied by New York City's Pennsylvania station. Its faucets were solid silver, piping was bronze. Instead of taking favored guests to the club, the Roman host took them to the public bath; after a tiring day, the average business or professional man sought shelter in the coolness and grandeur of the public bath.

Central Warm Air Heating

However, private bathrooms were enjoyed by the wealthy classes long before and during the public baths. In a typical upper class home in Pompeii, the bath itself was a complete room, the entire floor being submerged. Three or four steps led down



Vertical cross section of a three channel Roman aqueduct. This enabled carrying three different kinds of water over the same arches, or increasing capacity without widening arches

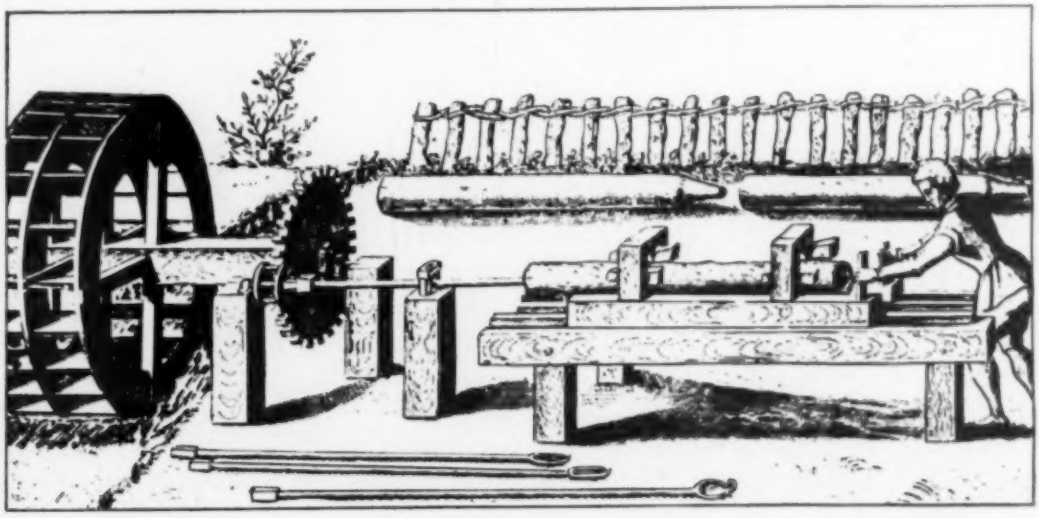
to it from the floor level of the main part of the house. The floor of the bath was of concrete slabs and the walls were lined with marble back of which were hollow terra cotta tile. In a hollow place under the floor, called the hypocaust, a fire would be built, the heat passing up through the hollow walls and warming the water and the air above it. This bathroom was a type found all over the ancient world where the Romans were influential.

In cool weather the warm air from the bathroom was allowed to circulate through the whole house. Also, after the bath was over and the fire burned out, a vent was opened to permit the smokeless air, heated by the hot walls and supporting structures under the bathroom, to circulate through the house. This probably led to heating systems where all the heat was circulated through terra cotta pipes and tile to the rooms above. In Ostia, the seaport city of ancient Rome, the wealthy middle class lived in beautiful apartment buildings, 10 or more apartments to each building and all heated by warm air conducted through baked clay pipes from a furnace room in the basement. These heating systems were not very efficient, but then there were plenty of slaves to haul fuel and to stoke. It is interesting to note that such terra cotta pipe was frequently tapered, the shape used by the Cretans who probably originated terra cotta 1500 or more years before.

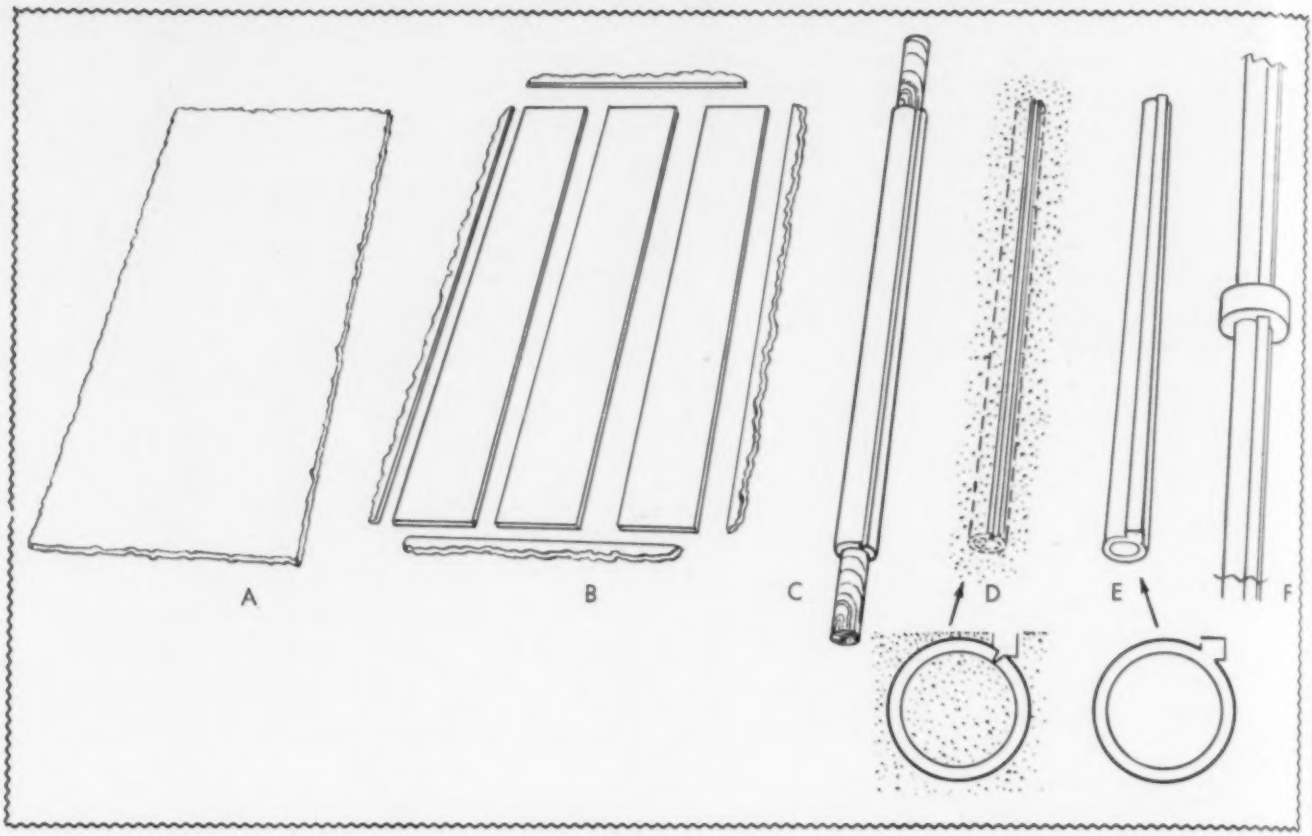
Ancient Rome's Water System

At the time of Frontius who, at 97 A. D., was *curator aquerium*—chairman of the metropolitan water board, we would say—332,000,000 gal of water was delivered daily over Rome's nine aqueducts, or 332 gal per person. This figure, however, is based on one very conservative estimate of the population; other estimates range up to 4,000,000 population, including slaves and visitors.

The nine aqueducts of Frontius' time and their 247 auxiliary reservoirs supplied 39 ornamental fountains, 591 public water basins, and thousands of residences—of which there were over 1400 mansions or palaces, well over 14,000 rooming houses (hotels) and many more houses of the middle class. A 10th aqueduct supplied the Circus Maximus only. The amphitheater proper of this huge structure, which seated 385,000, had a watertight wall extending down from the first row of seats and a watertight, masonry lined bottom. These enabled covering the floor with water deep enough to float warships. The warships were manned with gladiators



Water powered wood pipe boring machine, of a type used from the latter Middle Ages on



and prisoners of war who, divided into two sides, fought it out to the death, before a screaming, half-mad multitude.

Every house, except those of the poor, had at least one water supply piped to it and probably one or more inside or outside fountains for decoration and cooling effect and to provide continuous flushing for the drain. There was a considerable difference in the taste and purity of water delivered over the various aqueducts and it was desirable to have one for drinking, another for bathing and washing, and possibly a third for fountains and lawns. Water to private homes was metered and paid for at different rates for different quality, the meters being sections of pipe of various inside diameters. Apparently the Romans were not above reaming out meters to larger size, for the city eventually found it had to require that meters be of bronze instead of lead. Some home owners had to run their own piping all the way to the reservoir nearest them, although under many streets there were mains as we know them today. Under the principal thoroughfares the mains were in tunnels, to facilitate maintenance, just as our big cities have them today.

The Roman sewer and drainage system was excellent. Every house had a drain that led to the street drain or sewer, and usually inclining rather steeply. The surplus water from the aqueducts and the water from the many public and private fountains kept the sewers flushed constantly. One large sewer, 11 by 14 ft with an arched roof and lined with large stone blocks, was in use until 30 years ago.

The "Plumberius"

The "plumberius" of ancient Rome was the fellow who kept all this going. He was a combination waterworks engineer, sewer engineer, pipe maker, and plumber. Looking through his technical eyes we can see how it was necessary to go out in various directions from Rome to get sufficient water and of the quality the Romans were willing to pay for. The aqueducts that brought in this water had to incline gradually and uniformly toward Rome, lying on the surface where possible, penetrating the hills in tunnels, and bridging the valleys on arches where necessary. It was fortunate for Rome that the topography of the surrounding country inclined generally toward the city and that it had considerable timber, rock, clay, and lead for aqueducts and piping.

How the Romans made lead pipe. (A) They cast a sheet of lead 10 ft long and as thick as they wanted pipe walls to be. (B) Trimmed sheet and cut it into strips, width depending on size of pipe. (C) Curved strips around wood cylinder. (D) Filled pipe with sand and buried it in sand so that v shaped juncture opened to a molded trough which was filled with hot lead. (E) Finished pipe, showing extended seam. (F) Joint of two sections of pipe showing molded collar

Three hundred and four of the 359 miles of water conduit that eventually led to Rome were on or beneath the surface; the remaining 44 miles were on graceful and sturdy arches built as high as 109 ft (arches in the provinces were as high as 165 ft). These arched passageways supported as many as three ducts, built one above the other to enable bringing different kinds of water over the same structure and to increase capacity without widening the supporting structure. Aqueducts were built of stone and usually lined with masonry; occasionally a top duct would be of brick. Metal lining was rarely used. In a few instances aqueducts did not cross depressions on arches but were lined with lead piping, the flow of water down the decline forcing it up and over the incline on the opposite side. Aqueduct elbows were sometimes hollowed out huge chunks of stone. Standard practice was to throw ashes into the stream to fill small leaks in the masonry.

How Much Water Pressure?

Just how much water pressure or what range of water pressures Rome's water system offered is a matter of interesting speculation. We know the Romans had no hydraulic pumps, no mechanical means of elevating large quantities of water into a standpipe. We do know that some of the aqueducts terminated on arches, so they offered this much additional water pressure. Their reservoirs must have been built prominently above the ground or on the sides of hills. Pliny

wrote that "If you wish to deliver water above an eminence you have to use lead piping." However, the water pressure was never greater than the weight of the column of water from the water level in the reservoir to the tap in the subscriber's home, as all flow was by gravity.

Answering the water pressure question would require a study of the topography of the ancient city itself, locating its aqueducts and reservoirs. It is very doubtful if it was ever expected to deliver water in pipes to the 70 ft limit to which houses could be built, at least not in the higher parts of the city. Even then it would have been necessary to have a private line direct to the reservoir, as a main delivering a constant flow to many private homes would not offer much pressure at any one outlet. It is probable that the residents of top floors carried their cooking and fire-quenching water up from the lower floors. The mansions had their bathrooms on the first floor, a clue. The people living on the upper floors of the apartments must have depended upon the public baths entirely. Samples of lead pipe made exactly as the Romans made it will withstand pressures of as much as 250 psi. However, it was probably made with walls this thick because of the limitations of method and to withstand external pressure and wear, as piping was not always protected or in deep trenches.

Pipe Making

Pipe making was "big business" with the ancient Romans, the industry centering at Rome, Pompeii, and Bath, England. Pipes as small as ¾ in. and as large as 27 in. diameter with 1¼ in. wall thickness have been found, and lining some of the aqueducts must have called for even larger diameters. Wall thickness of Bath pipe was only 0.25 in., of Pompeii pipe 0.36 in. Rome pipe thickness varied as to diameter, and standards were maintained. The writer Vitruv, 24 B. C., says: "These must not be shorter than 10 ft. A pipe 100 in. long must weigh 1200 lb, and an 80 in. pipe 960 lb . . . a 5 in. pipe 60 lb." The inches indicated the width of the strip from which the pipe was formed, its circumference.

In making lead pipe the Romans first cast a flat sheet of lead about 10 ft long, trimming this and cutting it into strips, width varying with the diameter of the desired pipe. These strips were either folded over (almond shape cross section) or curved around a wood cylinder (round) until the two inside edges touched, leaving a v shaped opening. This v shaped opening was not merely soldered shut, but closed with an extended, square shaped, cast seam. The pipe was filled with sand and buried in sand with a narrow trench covering the seam and opening to the top. The edges were preheated with a hot iron, the metal poured, and the surplus carefully trimmed away.

Sections of lead pipe were joined by filling the ends with sand, butting them together, and building a sand mold around them that would cast a reinforcing collar. The hot metal was poured into the collar cavity, overflowing into a small weir until the ends of the sections fused together. Fusion was determined by probing with a splinter of wood until penetration to the sand core was no longer possible. This method was used until after 1500, many years after the introduction of the wiped joint.

Trademarked Pipe

It was the practice of the Roman plumber to mark all pipe with his name and with the name of the customer. The customer wanted his name on the pipe so that there would be no excuse for a neighbor's tapping in on his line and claiming that he (the neighbor) thought it was the city main. Feminine names are found on some of these pipes, indicating that women were in possession of some plumbing businesses. Women would not have worked, as anyone wealthy enough to own such a business could afford slaves.

Faucets very similar to simple types we have today were in general use in ancient Rome. The Roman pipe makers also cast turns, tees, and crosses. Some terra cotta pipe was used for water systems and was favored by a famous Roman architect, who said that terra cotta pipe made the water purer and tastier, and anyone could repair it. He also said that its walls should be about two fingers thick and should be tongued at the end so that they would fit one into the other. A cement of quicklime and oil was recommended for lining the joints.

IMPROVES OIL COMBUSTION WITH PHOTO-ELECTRIC SMOKE ALARM

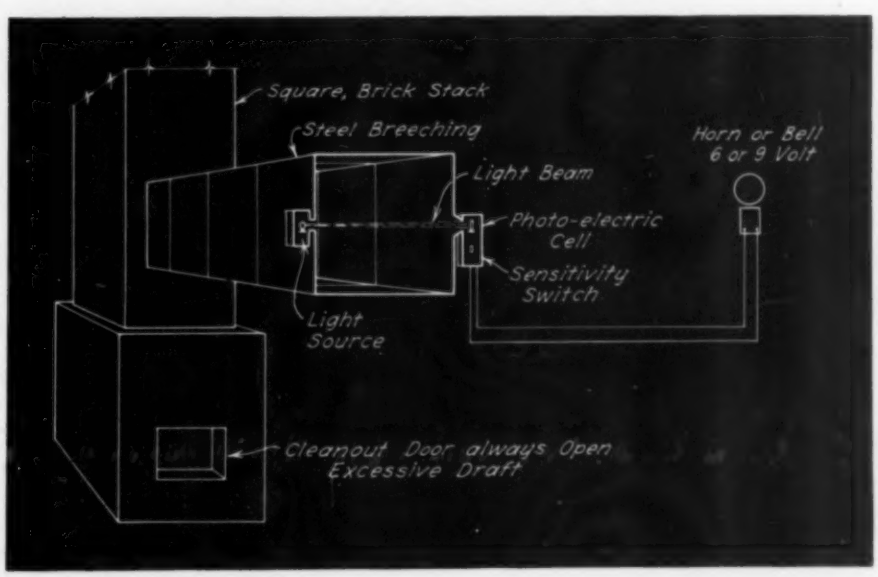
I CLAIM a man who doesn't read the advertisements doesn't get his money's worth. You get much good, practical, and timely dope in the ads.

I have an electric eye warning signal hooked up with my oil burners so that I know the instant they start smoking, regardless of what part of the plant I may be in. I picked up this idea from an advertisement that had no connection with my type of work at all.

We are using bunker C oil. In order to handle this oil, with no steam in our storage tank, we have to pump back hot oil into the storage tank, not allowing the oil in the tank to get below 75 F. At times, the oil in the line would cool off and then automatically come on and the cold oil would strike a cold firebox. The result would be a No. 2 smoke. This we did not know at the time, our only check for smoke being a barrel top painted white in the cleanout door at the base of the stack.

Since we have installed the photo-electric smoke detector, we have an average CO_2 of 14.3, where with our former operating condition we only averaged 10½ to 11. I think you will agree with me that a No. 2 smoke on the Ringelmann chart cannot spell as near perfect combustion as no smoke. —BARNEY MEYER, master mechanic and chief engineer.

A photo-electric smoke detector has allowed the operating force to improve combustion results of an oil fired plant



AUTOMATIC VALVE CONTROL GOVERNS FLOW IN WAR PLANT PIPING SYSTEMS

Operator's section of a typical "robot" control being tested before shipment for installation. The method can be used for opening and closing dozens of valves in processing aviation gasoline, butadiene for synthetic rubber or toluene for explosives

A "ROBOT" control which opens and closes dozens of valves with split second timing now controls processing in many of the nation's war plants producing aviation gasoline, butadiene for synthetic rubber, and toluene for explosives. In such plants steam, air, and hot gases flow intermittently through a complex system of piping and tanks. These gases must follow each other at predetermined intervals, and any error in timing or route of flow would slow up production not only through loss of materials but by possible damage to equipment.

The processing might be compared to the job of scheduling, dispatching, and regulating trains on a congested railroad system. One small error can tie up railroad traffic for hours, possibly resulting in collisions which would damage both trains and goods in transit.

The valve control performs the same functions in gasoline, butadiene, and toluene plants as dispatchers and switchmen do in a railroad system. In many of these plants, even if the required numbers of skilled operators were available, it would be humanly impossible for them to open and close the numerous valves with the precise timing provided by the control, consisting of automatic cycle timers and valve control.

The controls govern the flow with machinelike precision, minimizing the possibility of human error. If something goes wrong, such as a valve sticking open or shut, the control even voices a warning—it summons an operator by blowing a horn, or ringing a bell.

The operator's section of the control consists of a long panel somewhat resembling the main switchboard in a telephone exchange. Covered with banks of switches, dials, lights, and other indicators, it is the focal point for valve control. When a valve is opened or closed, a light on the board goes on. If any valve should fail to open or close, the board automatically suspends further operations and sounds the alarm for an operator. A glance at the board gives the operator the trouble location and he can arrange for quick repairs.

Before the war this equipment was developed principally to produce high octane gasoline for planes and cars. Because the same methods may be used in producing butadiene and toluene, it is now widely used in these two types of plants as well. Plans for extension to other types of plants requiring precise timing or valve control are also under way.—B. M. MILLS, industrial engineering div., General Electric Co.

Heating·Piping·Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

Graphical Method of Calculating Heat Losses

By Paul D. Close,* Chicago, Ill.

SUMMARY—The author presents a chart as a time-saver in calculating heat losses for one-, one and one-half, and two-story residences.

THE PURPOSE of this paper is to present a graphical, time-saving method of calculating heat losses. Although the chart (Fig. 1) is applicable mainly to simple structures such as one, one and one-half, and two-story residences, the same principles can be adapted to other types of buildings.

This graphical method was developed on the basis of the fundamental equations for building heat losses. It is not intended to supplant the ASHVE Guide procedure, but it may be useful for checking the Guide result in many cases, or for obtaining a reasonably accurate answer in a minimum of time. Since the calculation of building heat losses is not and cannot at best be an exact science, an approximate answer may suffice in many cases. The result obtained by this chart will generally check within ± 3 per cent of the Guide result when the same coefficients and surface areas are used in both cases.

Basis of Derivation

The heat losses of a building are classified as (1) the transmission losses through the exposed surfaces such as the walls, ceiling, floor, glass, and door areas, and (2) the infiltration losses due to air leakage through cracks, crevices, and other openings. The transmission losses are a direct function of the areas of the exposed surfaces and their respective heat loss coefficients and the temperature difference. The infiltration losses are a function of the volume of outside air entering the building which must be translated into the heat equivalent required to warm this air from the outside temperature to the inside room temperature.

Symbols

The symbols used in the development of the formulae from which the curves of Fig. 1 were plotted are as follows:

U_w = coefficient of transmission of exterior walls (Btu per hr per sq ft per deg temperature difference);

U_g = coefficient of transmission of glass surfaces (Btu per hr per sq ft per deg temperature difference);

U_c = coefficient of transmission of top floor ceiling (plus roof) (Btu per hr per sq ft per deg temperature difference);

U_f = coefficient of transmission of floor (Btu per hr per sq ft per deg temperature difference);

A_1 = net wall area, sq ft (inside dimensions);

A_2 = net glass and door area, sq ft (inside dimensions);

A_w = gross wall area = $A_1 + A_2$ (inside dimensions);

A_c = ceiling area, sq ft (inside dimensions);

A_f = floor area, sq ft (inside dimensions);

H_d = heat loss of building per 1 deg temperature difference, Btu per hr.

Transmission Losses

The wall and glass transmission losses *per degree temperature difference* are expressed by the following equation:

$$\textit{Wall and glass transmission losses} = A_1U_w + A_2U_g \quad \ldots (1)$$

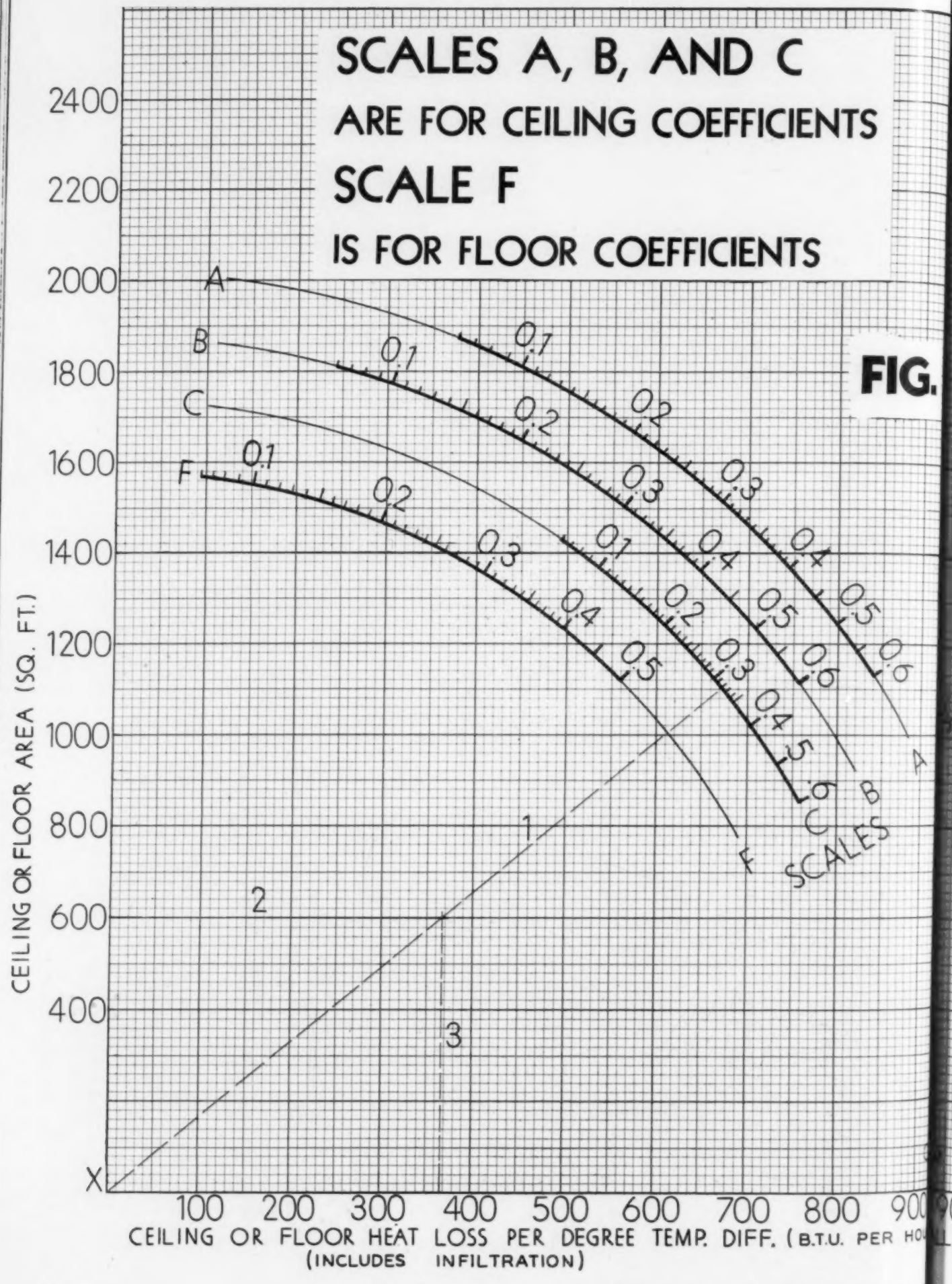
It will be noted that the area factor (A_2) includes both the glass and door areas, whereas the coefficient factor (U_g) is for the glass heat loss coefficient. Actually the door coefficient will be lower in the case of solid wood doors than the glass coefficient, but since the door area is relatively small, the glass coefficient may be used for both the glass and door surfaces.

The glass and door areas of most residences range between 15 and 25 per cent of the gross exterior wall area (based on inside dimensions) or an average of 20 per cent. In order to simplify the procedure, this average glass and door area is assumed. A few trial calculations will show that there will be a comparatively small variation in the final result due to any small deviation from this average figure, provided the correct gross wall, glass and door area (A_w) is used. Substituting this ratio of glass and door area in equation 1, the wall and glass transmission loss becomes:

$$\textit{Wall and glass transmission loss} = (0.8U_w + 0.20U_g)A_w \quad \ldots (1a)$$

*Technical Secretary, Insulation Board Institute. Member of ASHVE.

For presentation at the Semi-Annual Meeting of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa., June, 1943.


SCALES A, B, AND C
ARE FOR CEILING COEFFICIENTS
SCALE F
IS FOR FLOOR COEFFICIENTS
FIG.
CEILING OR FLOOR AREA (SQ. FT.)
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2200
2000
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0.1
0.2
0.3
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SCALES
1
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3
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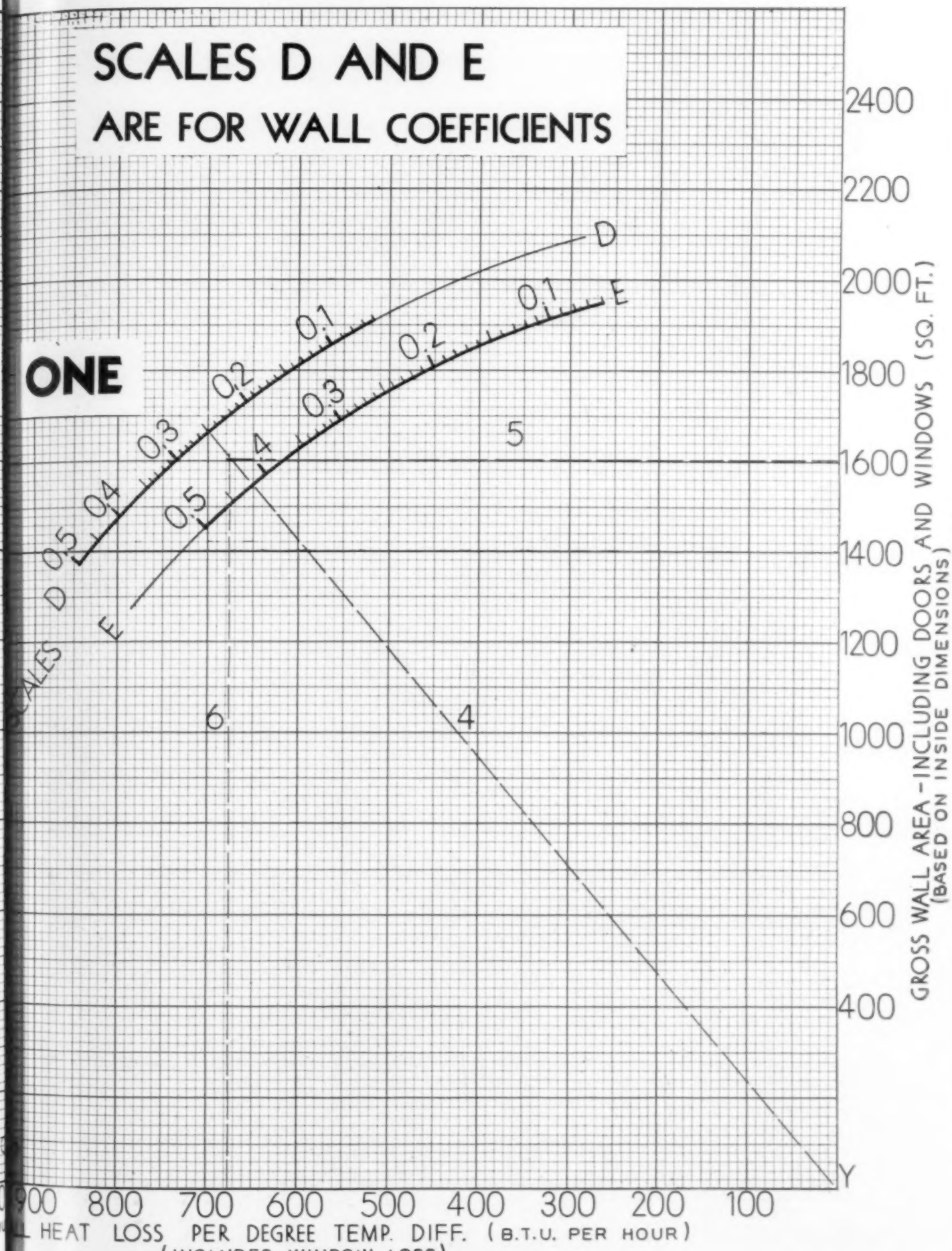
CEILING OR FLOOR HEAT LOSS PER DEGREE TEMP. DIFF. (B.T.U. PER HO
(INCLUDES INFILTRATION)


SCALES D AND E
ARE FOR WALL COEFFICIENTS
ONE
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GROSS WALL AREA - INCLUDING DOORS AND WINDOWS (SQ. FT.)
(BASED ON INSIDE DIMENSIONS)
Y
900 800 700 600 500 400 300 200 100
HEAT LOSS PER DEGREE TEMP. DIFF. (B.T.U. PER HOUR)
(INCLUDES WINDOW LOSS)

Table 1—Scales of Fig. 1 to be used for calculating heat losses

Stories	Basement	No Storm Windows or Doors						With Storm Windows and Doors					
		No Weatherstrips			With Weatherstrips			No Weatherstrips			With Weatherstrips		
		Ceiling	Wall	Floor	Ceiling	Wall	Floor	Ceiling	Wall	Floor	Ceiling	Wall	Floor
One-Story Houses	With basement[a]	A	D		B	D		B	E		B	E	
	No basement[b]	A	D	F	B	D	F	B	E	F	B	E	F
1½ Story Houses	With basement[a]	C	D		A	D		A	E		A	E	
	No basement[b]	C	D	F	A	D	F	A	E	F	A	E	F
Two-Story Houses	With basement[a]	C	D		A	D		A	E		A	E	
	No basement[b]	C	D	F	A	D	F	A	E	F	A	E	F

[a]Also for houses without basement but with first floor directly on ground.
[b]Floor above ground with air space between.

The ceiling transmission loss per degree temperature difference is equal to the ceiling coefficient (U_c) times the ceiling area, or

$$\textit{Ceiling transmission loss} = U_c A_c \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The ceiling coefficient (U_c) should also include the value of the roof whether flat or pitched. Consequently, the combined ceiling and roof coefficient should be used for the value of U_c.

Floor Transmission Loss

According to data in the ASHVE Guide 1943, the floor loss for houses with basements may be neglected. Similarly, the floor loss into the ground for houses with the floor located directly on the ground is comparatively small and may be neglected. If, however, the house has no basement and is placed on piers so that the space under the floor is exposed to air at or near the outside temperature, then an allowance should be made for the heat loss through the floor into this space. The floor transmission loss per one degree temperature difference in the latter case is as follows:

$$\textit{Floor transmission loss} = U_f A_f \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Infiltration Losses

The air change method was used for estimating infiltration, the allowance being one air change per hour for houses without weatherstrips or storm windows and one-half air change per hour for houses with either weatherstrips or storm windows. Using this assumption, it will be found that the total heat loss will not vary appreciably in the average case from that obtained by the crack method given in the Guide, using double-hung wood windows of average width of crack. Based on an 8 ft ceiling height (assumed in this case), the heated volume of a one-story house will be $8A_c$ and the infiltration allowance for a one-story house without storm windows or weatherstrips (assuming one air change per hour) will be:

$$\left.\begin{array}{l}\textit{Infiltration loss (one-story house)}\\ \textit{(No storm windows or weatherstrips)}\end{array}\right\} = \frac{8A_c}{55.5} = 0.144A_c \quad \ldots\ldots\ldots (4a)$$

With two-story houses, the volume will of course be greater for the same perimeter or top floor ceiling area. For example, in the case of a two-story house, the volume will be equal to the flat or projected top floor ceiling area (A_c) times the sum of the ceiling heights of the two floors, or for an 8 ft per floor ceiling height, the volume will be $16A_c$ and the infiltration allowance for a two-story house without storm windows or weatherstrips (assuming one air change per hour) will be:

$$\left.\begin{array}{l}\textit{Infiltration loss (two-story house)}\\ \textit{(No storm windows or weatherstrips)}\end{array}\right\} = \frac{16A_c}{55.5} = 0.288A_c \quad \ldots\ldots\ldots (4b)$$

Since for houses with storm windows or weatherstrips, the infiltration allowance is one-half an air change per hour instead of one air change per hour, the infiltration losses with storm windows or weatherstrips will be one-half the losses for houses without storm sash or weatherstrips given in equations 4a and 4b, or $0.072A_c$ and $0.144A_c$ respectively for one and two-story houses.

An 8 ft ceiling height was assumed for estimating the infiltration allowance because this ceiling height is becoming more or less standard practice in current low-cost housing. However, ceiling heights of 8½ and 9 ft were commonly used in the older houses, but it will be found that the glass area percentage in these older houses generally averages less than 20 per cent, which compensates for the higher ceiling heights. Even disregarding any possible compensating effect due to a less-than-20-per-cent glass area, an actual ceiling height of 9 ft instead of 8 ft, as assumed for the chart, would increase the calculated infiltration allowance by ⅛ or 12½ per cent. Inasmuch as the infiltration allowance may be only a small percentage—10 to 20 per cent in many cases—of the total heat loss, the error due to the assumption of an 8 ft ceiling height will usually be comparatively small when considered from the standpoint of the total heat loss of the building.

Total Heat Loss

The total heat loss per degree temperature difference is of course equal to the summation of the wall and glass transmission loss, the ceiling (plus roof) transmission loss, the floor transmission loss (if any) and the infiltration loss. For example, the heat loss per degree temperature difference (H_d) for a one-story house without

Table 2—Factors for estimating amount of fuel required per average heating season, based on inside temperature of 70 F

Note: These factors when multiplied by the heat loss of the building per 1 deg temperature difference (H_d) and by the thousands of degree-days per heating season will give the approximate amount of fuel required per average heating season based on an inside temperature of 70 F.[a]

Fuel	Assumed Calorific Value	Method of Firing	Assumed Heating Efficiency	Factor	Result Will Be
Coal	13,000 Btu per lb	Hand-fired (Residence)	0.50	0.00185	Tons of Coal
		Stoker (Residence)	0.60	0.00154	
		Stoker (Industrial)	0.70	0.00132	
Oil	141,000 Btu per gal	Conversion	0.60	0.284	Gallons of Oil
		Oil-Designed	0.75	0.226	
Manufactured Gas	535 Btu per cu ft	Conversion	0.65	0.069	Thousands Cubic Feet Manufactured Gas
		Gas-Designed	0.80	0.056	
Natural Gas	1000 Btu per cu ft	Conversion	0.65	0.0369	Thousands Cubic Feet Natural Gas
		Gas-Designed	0.80	0.030	

[a]Example: The heat loss of a certain building (from Fig. 1) is 1200 Btu per hr per degree temperature difference and is located in a city having 6500 degree-days. The probable fuel consumption in coal (hand fired) will be $0.00185 \times 1200 \times 6.5 = 14.4$ tons.

storm windows or weatherstrips and with a basement (neglecting the floor loss) using the values in equations (1a), (2) and (4a), but omitting (3), will be:

$$H_d = (0.80U_w + 0.20U_g)A_w + U_cA_c + 0.144A_c = (0.80U_w + 0.20U_g)A_w + (U_c + 0.144)A_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

This formula can be further simplified by substituting the value of $U_g = 1.13$ (for single glass), in which case the quantity $0.20U_g$ becomes 0.226 and the formula for a one-story house with basement and without storm windows and weatherstrips then becomes:

$$H_d = (0.80U_w + 0.266)A_w + (U_c + 0.144)A_c \quad \ldots\ldots\ldots (5a)$$

In a similar manner, equations may be developed for one-story houses with storm windows or weatherstrips and for two-story houses and also for houses without basements. Wherever the floor heat loss is to be included, the quantity (U_fA_f) given in equation (3) will appear. For example, the equation for a one-story house similar to that for which equation (5a) is applicable but without basement and with the floor above ground so that there is an air space underneath, will be as follows:

$$H_d = (0.80U_w + 0.226)A_w + (U_c + 0.144)A_c + U_fA_f \ldots (6)$$

Heat Loss Charts

The chart (Fig. 1) was developed by plotting these and other similar equations. For instance, Scale A for ceilings is a plot of the quantity $(U_c + 0.144)A_c$, which appears in equations (5), (5a), and (6) and is applicable to one-story houses without storm windows or weatherstrips. This quantity of course includes the infiltration loss. The other scales in Fig. 1 are plotted from the following equations:

Scale B (for ceilings): $(U_c + 0.072)A_c$.
Scale C (for ceilings): $(U_c + 0.288)A_c$.
Scale D (for walls): $(0.80U_w + 0.226)A_w$ (for single glass).
Scale E (for walls): $(0.80U_w + 0.09)A_w$ (for double glass).
Scale F (for floors): U_fA_f.

How to Use Chart

The solution of any heat loss problem by means of this chart involves first the selection of the proper scales from Table 1. These of course depend upon the requirements of the problem.

The next step is to locate the ceiling (plus roof) coefficient on Scales A, B, or C and draw a line to point X, calling this Line 1. Next find the ceiling area on the left hand scale and draw a horizontal line to Line 1, and then a line vertically downward to the horizontal scale. The result indicated will be the ceiling heat loss per 1 deg temperature difference. This result includes the infiltration allowance.

The wall and glass heat loss is determined in a similar manner using Scales D or E. If the floor heat loss is to be included (as indicated by Table 1), this may be determined by means of Scale F and the left hand area scale, as with the ceiling heat loss.

The wall and ceiling—or wall, ceiling, and floor—losses, as the case may be, should be added, the result being given in terms of the heat loss for the building per 1 deg temperature difference. This should be multiplied by the total temperature difference for the location of the building. The gross exterior wall area (based on inside dimensions) and including doors and windows should be used in connection with Fig. 1. Similarly, the ceiling area is based on inside dimensions.

Example 1: Calculate the heat loss of a 20 x 30 ft (inside dimensions) two-story uninsulated frame residence with basement and without storm windows or weatherstrips located in Chicago. The ceiling height is 8 ft. The wall coefficient is assumed to be 0.25 and the ceiling-roof coefficient is assumed to be 0.32.

Solution: According to Table 1, Scales C and D of Fig. 1 should be used for this problem. Scale F is not used because the residence has a basement and the floor heat loss is therefore neglected. The solution of this problem is indicated by the dotted lines on Fig. 1. The gross wall area is 1600 sq ft and the ceiling area is 600 sq ft. It will be noted that the ceiling heat loss is approximately 367 Btu per hr per deg temperature difference. This result includes the infiltration allowance. The wall and glass heat loss, according to Fig. 1, is 678 Btu per hr per 1 deg temperature difference. The sum of these quantities is 1045 Btu per hr per 1 deg temperature difference. Assuming an inside temperature of 70 F and an outside temperature of —10 F, the temperature difference will be 80 F and the design heat loss will be 80 x 1045, or 83,600 Btu per hr.

Although this chart is intended specifically for residences, it can be adapted in certain cases to other types of structures such as small office buildings or factories. Similar charts may however be developed for other structures.

Example 2: Assume a small one-story factory, 20 x 50 ft, having a ceiling height of 8 ft, plain 8 in. brick walls and a 4 in. concrete roof deck with 1 in. of insulation, located in New York and exposed on all sides.

Solution: The coefficients are respectively 0.50 for the walls and 0.18 for the roof. The wall area is 1120 sq ft, the ceiling area is 1000 sq ft, and the heat losses according to Fig. 1 using Scales A and D will be 320 (ceiling) plus 695 (walls) or 1015 Btu per hr per deg temperature difference. If the temperature difference is 70 deg, the design heat loss will be 1015 x 70, or 71,050, or say 71,000 Btu per hr.

Estimating Annual Fuel Consumption

The approximate average annual fuel consumption can be estimated by multiplying the heat loss per 1 deg temperature difference (H_d) obtained from Fig. 1, by the number of thousand degree-days and by the factors given in Table 2 for various fuels. The assumed efficiencies and calorific values on which these factors are based are indicated in the table so that the factors may readily be modified on the basis of other efficiencies and calorific values, if desired. While the efficiencies in this table agree substantially with the values in use by a local public utility, it is realized that there may be a wide variation in combustion efficiencies encountered in actual practice and where specific data are available, the factors in Table 2 should be modified accordingly.

Degree-days calculated on a 65 F base are applicable to an inside temperature of 70 F. Consequently the factors in Table 2 are applicable only to this inside temperature. For lower inside temperatures, the fuel consumption will be correspondingly less, and vice versa. For other *average* inside temperatures than 70 F, the estimated fuel consumption can be adjusted on the basis of the ratio of the inside-outside temperature difference. For example, if the average day and night temperature is 65 F (instead of 70 F) and the building is located in a city where the average outside temperature during the heating season is 30 F, the fuel consumption will be reduced in the ratio of (70-65)/(70-30) or 5/40 or 12½ per cent. Average outside temperatures during the heating season (assumed to be from October 1 to May 1, or seven months) are given in Table 2 on pp. 132 and 133 of the Guide 1943. There will be a slight error in some cases when using these average outside temperatures because of the fact that the actual heating season may be of greater or lesser duration than seven months.

Limitations of Chart

As previously stated, this chart is intended for one, one and one-half, and two-story houses, but it may also be used for small one and two-story office buildings and factories, if the conditions are similar to those on which the chart is based. It is not expected, however, that every one or two-story residence heat loss problem can be solved by this type of chart as special or unusual conditions will be encountered.

A two-story house with a heated attic would be considered to be a three-story house so far as the ap-

plication of the chart is concerned. Since a maximum of two stories is provided for by the chart, it would be necessary to add another scale to the chart for three-story houses, although the error would be small if the problem were solved as if the house were of two stories, provided the proper gross wall and top floor ceiling areas are used. The actual error resulting from this assumption would be that due to the infiltration allowance being for a two-story house instead of for a three story building.

Unheated garages and sleeping porches should be neglected and the building considered as if they were not a part of the structure. Heated garages and sleeping porches maintained at room temperature should of course be figured the same as other heated rooms or spaces. If the temperature maintained in such spaces is lower than the inside room temperature, the heat losses from such rooms or spaces will be correspondingly reduced. If these spaces are comparatively small and are to be heated at all, it will usually be sufficiently accurate to consider them to be maintained at room temperature.

Since no allowance is made for heated basements used, for example, for living quarters, the heat losses from such spaces may be considered by adding the basement floor and wall heat losses to the heat loss for the remainder of the structure, basing the calculations on the proper surface areas, coefficients, and temperature differences.

LOWER COST HOUSING PREDICTED

In an address before the Edison Electric Institute at Chicago, Ill., Irving W. Clark predicted that 70 per cent of the post war houses cost only $3,000 to $6,000. The need for one million housing units annually, for 10 years or longer after the war, if we as a nation are to meet the needs for housing, is based upon long-term studies which clearly establish the following facts: *first*, the net increase of new families that come into being annually in the United States is approximately 500,000; *second*, the number of houses destroyed by fire, tornadoes and other catastrophes or razed because of total obsolescence every year averages about 400,000. Need for housing is one thing while the actual number of homes that may be built is quite another factor.

Most new homes that begin springing up when peace comes will not be radically different from those built just before war. It is sound to anticipate that equipment and materials will be the same or similar to those with which we dealt in 1942.

Many of the elements, materials and products pictured as *things of the future* will eventually become fact. The history of all products has been one of the improvements through research and development—step by step. While many new materials have been developed for use in war products, their application to peace will require a period of further research and development.

MRS. O. E. FRANK HEADS PATERSON ZONTA CLUB

Mrs. Olive E. Frank, president of Frank Heaters, Inc., Paterson, N. J., was elected president of Paterson Zonta Club at a dinner held recently at the Y.W.C.A. Mrs. Frank has been a member of the ASHVE for 24 years, and is well known in engineering circles. She is also a member of the *ASME*. She has been a member of the Zonta, service club for women, for many years, having formerly been a member in Buffalo, N. Y., where the organization had its inception.

At the dinner a report was made on the work at the canteen at USO headquarters, which Zonta has conducted since the center for service men was opened. Following the business session, a talk was given on the subject of *Dogs for Defense*, in which a plan for using dogs in many branches of the service was outlined. An appeal was made for the War Dog Fund, through which owners may *enlist* their dogs to aid their canine brothers in being sent to the front.

VISITING U. S. A.

Two Society members who recently visited the Society headquarters were D. L. Baker, San Juan, Puerto Rico, and Julius Demeter, Santiago, Chile, who have returned to the United States for a short time on business matters. Mr. Baker related some interesting experiences during the war period in various parts of the world while he was a Carrier Corp. representative. Both members reported an enjoyable time renewing old acquaintances during their brief trip in the United States, and expressed a desire to attend the Society's Semi-Annual Meeting at Pittsburgh.

SAVING IN VENTILATION COST

Definite economy in ventilation costs, by freeing coal mines of dangerous gas before a seam is worked, is being accomplished by sinking pipes into the ground ahead of the workings and pumping the gas out, the Compressed Air Institute reports.

This is being practiced at a mining operation near Bluefield, W. Va., where holes for the pipes are drilled to depths ranging from 100 to 1,000 ft, depending upon the thickness of the overburden between the coal and the surface. The pipes are sent a short distance through the collar of the holes and then connected to blowers which exhaust the gas.

Some of the mines where this is being done are extremely gassy, the Institute reports. One liberates as much as 12,000,000 cu ft of gas a day—enough to supply a large city.

Although the amount of inflammable methane must be kept to a maximum of 0.5 per cent in the mine atmosphere, it is the aim of this new gas evacuating process to reduce the amount of methane in the mine atmosphere 50 per cent before a coal seam is opened.

An idea of the economy of this method can be gained by considering that to get out 12,000,000 cu ft of gas from the mine and bring the methane content of the atmosphere to the required maximum would mean the circulation of 300,000,000 cu ft of air a minute by the usual means of ventilation.

NEW ASSIGNMENT FOR H. L. WHITELAW

Selection of H. Leigh Whitelaw, Pittsburgh, Pa., a member of the ASHVE for 27 years, as Managing Director of the Association of Gas Equipment and Appliance Manufacturers has been announced by Col. W. F. Rockwell, President of the Association.

H. L. Whitelaw

Mr. Whitelaw was trained as a production man in the plants of the American Radiator Co. and in 1913 he became manager of the smokeless boiler department of the company.

During the first World War Mr. Whitelaw was an administrative officer of the Royal Flying Corps and the Royal Air Force. He has been executive vice-president of the American Gas Products Corp., and recently was manager of utility sales for Jones and Laughlin Steel Co. He has been active in the AGA as sectional vice-president and chairman of the manufacturers section in 1927-28.

AIR CONDITIONING GOES TO WAR

L. W. Clifford, development engineer of Westinghouse Electric and Mfg. Co., East Springfield, Mass., told the Baltimore-Washington section of American Society of Refrigerating Engineers that by maintaining custom made atmospheres in armories, airports, flying schools and war plants, air conditioning apparatus once built only for the convenience of comfort loving Americans has become a vital tool in the war program.

Field Study of Comfort Reactions of Apartment Dwellers Under Fuel Oil Rationing

By Sallye Hamilton,* New York, N. Y.

SUMMARY.—This article presents a Fuel Oil Rationing Study made at Hillside Homes, in New York City, from November 16, 1942, to December 13, 1942. Special emphasis is placed on room air temperatures resulting from the fuel rationing program and the comfort of the families cooperating. The data included show fuel oil consumption and Weather Bureau data for test period; consumption of fuel oil, gas, and electricity; additional cost of gas and electricity, resulting from increased use of these to provide auxiliary heat; average living room air temperatures by apartments at 60 in. level, with apartment exposure and use of auxiliary heat in apartments during study; average living room air temperatures for all apartments at 30 in. and 60 in. levels for entire study; clothing practices and adjustments to low air temperatures in apartments resulting from fuel oil rationing; and the relation of clothing and activity to varying room air temperatures. The results prove that with a two-thirds fuel oil ration it is not possible to maintain a room air temperature of 65 F in apartments excepting, probably, in a very few most favorable ones that are near the boiler, which have a minimum cold surface exposure, and receive maximum sunshine. The average 60 in. level living room air temperature in 12 of the 49 apartments ranged from 61.8 to 64.9 for the entire test period, with the living room in most instances considered the warmest room in the apartment.

THE STUDY was made in a group of five apartment building units, Fig. 1, each unit having its own heating system, utilities, and meter room. Each of the five buildings has a boiler room arranged as shown in Fig. 2; four have three boilers; and the fifth, a smaller unit, has two boilers. One burner of each building is automatic. The fuel used is bunker C oil which is stored in steam heated tanks. All of the buildings have four floors with the exception of one which has a section with six floors served by elevators. Instead of a main entrance and a long hall, each building has a number of stairwells which serve from two to four apartments on each floor.

The 4 in. concrete basement floor, under which the steam mains run, is a few feet above the bare earth, and the walls are of brick 12½ in. thick with ⅝-in. plaster applied directly to the brick inside, (U=0.34). The floor to ceiling height is 8 ft 6 in. with a ⅝-in. plaster ceiling under the 4-in. cinder concrete that forms the floor above. The floor surface is wooden blocks set in mastic. The roof has cinder fill of varying depths on the concrete slab, 1-in. fiber board insulation, and five-ply felt roofing tar-coated with slag, (U=0.18).

The windows are steel casement without weatherstripping except that applied by a few individual tenants. Kitchens have unvented gas stoves and many tenants have portable electric radiant heaters.

The heating system is a two-pipe up-feed, low pressure vacuum return system, and the radiators are of cast-iron tubular type. Risers are exposed in the apartments, and branches are run to radiators above the finished floor.

In the present control method the fireman maintained an empirically determined temperature on a recorder mounted near the last riser in the line. Before rationing started, this insured that the most ill-favored apartments secured adequate heat and that the remainder of the apartments secured adequate heat or better with the residents generally controlling the excess by opening windows, or in isolated cases by turning off radiators.

The study covers the period from November 16 to December 13, 1942. Conservation of fuel oil had been in operation in Hillside Homes since June, 1942, for domestic hot water heating; and for space heating since the beginning of the present (1942-1943) heating season.

Selection of Apartments: The apartments used in the study, 49 in all, were selected with regard to (1) distance from boiler, (2) extent of cold surface, and (3) sunshine. The following exposure code method was used: *F*-avorable, *M*-iddle zone, and *U*-nfavorable. The *first* letter refers to distance from boiler; *F* indicating within 100 ft horizontal run; *U* within 100 ft of end of line; and *M* the middle zone between these. The *second* letter refers to exposed surfaces (walls, glass area, unheated floor or ceiling and windy location):

	WEIGHT
2 walls exposed	1
3 walls exposed	2
Unheated under floor	1
Unheated over ceiling	2
Windy location	1
Extra glass area	1

	TOTAL WEIGHT
Favorable	0-1
Middle	2-3-4
Unfavorable	5-6

The *third* letter refers to sunshine: *F* indicating S, SW, and ESW exposures; *M* the EW, NW, ES, NES, and NEW exposures; and *U* the N and NE exposures. For example an apartment designated as *FMU* has a *F*-favorable location as to distance from boiler, *M*-iddle group classification as to extent of cold surface, and *U*-nfavorable location to receive sunshine. Table 2 shows the number of apartments with *F*-avorable, *U*-nfavorable, and *M*-iddle group classifications, as to distance from boiler, extent of cold surfaces, and sunshine.

Methods of Approach: Previous to the time the study was begun a printed letter was sent to all the residents of Hillside Homes emphasizing the importance of a fuel oil rationing study at this critical time and describing in detail the three suggested methods to be used. It emphasized

Fig. 1—Hillside Homes, New York, N. Y.

*Director of Field Study, John B. Pierce Foundation.

For presentation at the Semi-Annual Meeting of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa., June, 1943.

that the principal purpose of this program was to determine how to reduce discomfort during a period of real fuel oil shortage.

It was explained to the residents that there were three basic ways in which fuel oil consumption could be kept within the allotment provided by the government rationing plan: reducing the temperature of indoor air throughout the normal heating period; reducing the time during which heat is supplied with the normal amount of heat supplied when heat is on; and reducing the space heated, for example by cutting off heat in bedrooms.

Methods Used During Test Period: Temperature Reduction of Indoor Air was the first method used. If the difference between the average temperature of the indoor air and the average temperature of the outdoor air during an entire heating season is reduced one-third, the fuel consumption will be cut one-third. Contrary to general impressions, simply reducing the indoor air to 68 F, or even to 65 F will not give a one-third cut in apartment fuel oil consumption in New York City, or in other localities having the same winter air temperature. For example, in January and February, the daytime indoor temperatures must be reduced to approximately 60 F to keep the fuel oil consumption within the allotment. Using this method, heat was to be supplied during the same hours as in previous years (*on* at approximately 6:00 a. m. and *off* between 9:45 and 10:45 p. m., depending upon the outdoor air temperature.)

This method could not be operated in the test because of certain characteristics of the heating system. Steam is introduced into the main pipe through a motor-controlled valve, at the end of one line in each building. The operating engineer had arranged a temperature recorder with the bulb nearly touching the last riser on the line and had determined by previous test that if the temperature recorded were a certain value the apartment farthest from the boiler would have heat. He also has found by test that if the aperture on the control valve were less than 40 per cent open, the steam would be condensed by the near radiators and fail to reach the more distant ones. As in mild weather the distant apartments received no heat from this system, the method was abandoned. The failure of this method in this test does not imply that it would not work in very cold weather in these apartments when the unbalancing effects of the long supply lines would be less, nor does it imply that this system would not work in small or more compact buildings.

Reduction of Temperature and Time was the second method used and in this method the main saving was effected by reducing the time heat was supplied. Heat was provided at the beginning and end of the day. Usually the two boilers in each unit were started at 6:15 a. m. with the burners and oil pressure adjusted to maximum capacity. The steam was usually turned on in the building about 15 min after the boilers were started.

The oil consumption was gradually reduced during the morning and the burners were cut off at some time between 10:00 a. m. and 1:00 p. m. depending upon the outdoor temperature. The boilers were started again between 3:00 and 5:00 p. m. and run until approximately 9:00 p. m. One boiler was usually cut off one-half hour earlier.

The fireman controlled the oil consumption by a limited control of the burner oil pressure and the use of extra units, one of which was automatic. The steam into the building was controlled by a differential valve, in the steam main operated to maintain a predetermined temperature on a recording thermometer which was mounted near the last riser on the end of the steam line, and which was observed by the fireman once an hour.

The assistant engineer of the project controlled the amount of oil consumed by changing the time of shut down and starting, basing his estimate on Weather Bureau reports and estimating that each burner in operation would use about 30 gal of fuel oil per hour. This method was employed in determining the daily consumption of the oil for the test period, using the fireman's daily log. The best way, that of sounding the tank daily at 6:00 a. m., could not be followed because of the shortage of men. The tank gages in the boiler rooms, while sufficiently accurate on long periods when an equalizing period was allowed between the delivery of oil and the reading of the gage, were not satisfactory on a day-to-day basis for test purposes, because the gages were unsettled for several days after the oil was added.

Table 4, giving the average living room temperatures of each apartment for the entire study, shows that 12 of the 49 apartments (24.5 per cent) had an average living room temperature at 60 in. level below 65 F; 2 apartments averaged below 63 F. While 37 of the 49 (75.5 per cent) had averages from 65 F to 72.2 F, this in no way signifies that the average temperature for the entire apartment for this group came within any such comfort range. These temperatures represent only those of the living room which was usually considered the warmest room in the apartment. If the temperature of all rooms of these apartments were averaged, the temperature would have been even lower. This is illustrated by the following temperature averages of sample apartments for

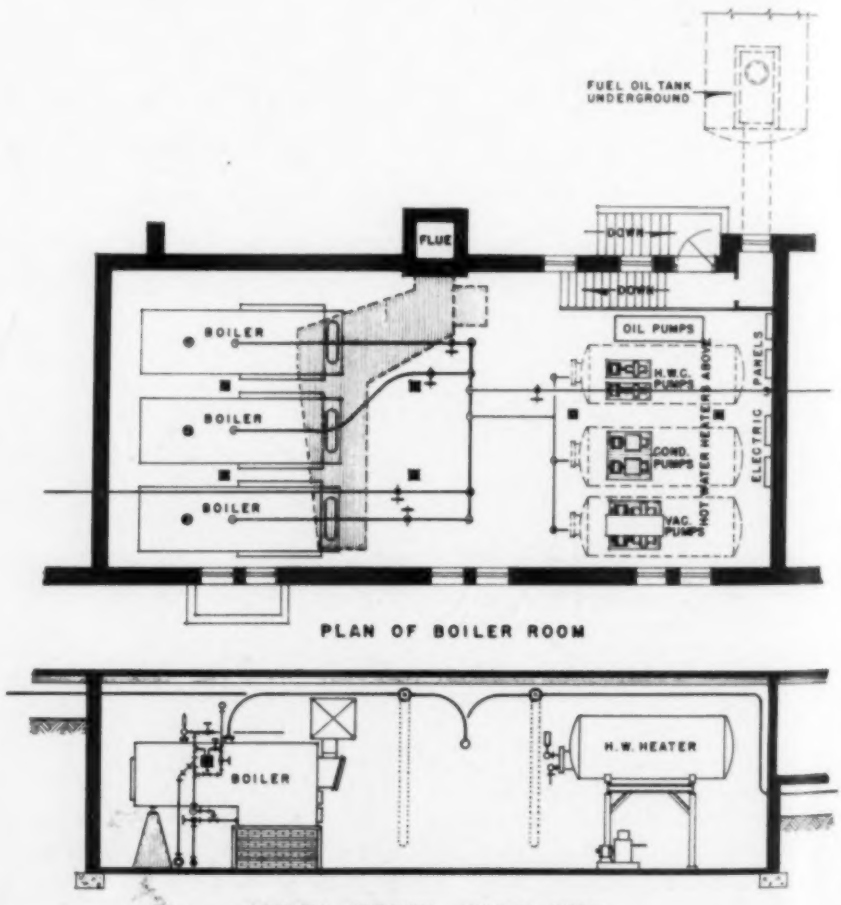

Fig. 2—Boiler room layout

Table 1—Hillside Homes—areas and statistics

Areas	
Land area excluding streets	14.18 acres
Net area of Typical Kitchen	83 sq ft
Net area of Typical Bath	37 sq ft
Net area of Typical Living Room	200 sq ft
Net area of Large Bedroom	188 sq ft
Net area of Small Bedroom	138 sq ft
Average gross area per room	221.6 sq ft

Apartments	Basement	Typical	Total
Total number of apartments	188	1.228	1.416
Total number of rooms	491	4.457	4.948

Costs and Rent	
Total population	5,250
Actual cost of construction: exclusive of architects' and builders' fees and carrying charges, Jan. 1, 1936	$4,481,111.
Landscaping, utilities, and ground improvement	176,344.
Total cost of projects excluding land to Jan. 1, 1936	5,041,445.
Total cost of land	448,169.
Cost of land	.70 sq ft
Average rent per room	11.00 (per month)

Architect: Clarence S. Stein
Structural Engineer: Rollin C. Bastress
Heating and Electrical Engineers: Eadie, Freund and Campbell

Table 2—Apartment exposure summaries

	Favorable	Middle Zone	Unfavorable
Boiler Location	16	16	14
Exposure to Cold Surfaces	12	23	11
Orientation to Sunshine	14	19	13

Table 3—Averages for all living room air temperatures for entire study

Readings			
	Morning	Noon	Afternoon
L. R. 30 in. Level	66.2	65.6	66.1
L. R. 60 in. Level	68.0	66.6	67.3

Table 4—General averages by apartment for entire study, November 16-December 13, 1942, air temperatures in living room

Apartment Code	Exposure Code	Time of Readings 9-11 a.m. L. R. 60 In.	12:30-2:30 p.m. L. R. 60 in.	4-6 p. m. L. R. 60	Average	Auxiliary Heat
59 D6	FMU	72.6	71.0	73.0	72.2	**
20 B2	UMF	71.4	71.8	72.1	71.8	***
85 A3	MMM	72.3	70.5	72.4	71.7	****
60 B4	UMF	72.5	71.4	70.0	71.3	***
79 A1	MMF	71.9	70 8	70 9	71.2	*
44 A1	UFM	72.8	70.4	69.7	71.0	*
60 A1	UUU	70.0	69.1	72.5	70.5	****
10 B1	FFF	70.8	70.3	69.5	70.2	*
57 C6	FUF	70.4	68.2	71.4	70.0	***
60 B1	UFF	69.6	69.9	69.4	69.6	***
63 B1	FFU	71.4	67.9	69.6	69.6	*
44 B1	UMF	69.6	69.2	69 1	69.3	*
79 B2	MMM	70 0	68.8	68.7	69.1	*
10 A1	FMU	69.8	68.3	69.6	69.2	****
63 A2	FFF	69.8	68.1	69.4	69.1	*
58 A2	MFM	68.9	69.3	68.3	68.8	*
88 A1	MUM	68.7	68 9	68.9	68.8	**
86 B1	FMM	69.9	67.5	68.7	68.7	***
79 A4	MMF	70.0	68.7	66.9	68.5	*
65 B1	FFU	68.9	68.4	67.3	68.2	*
28 B1	MMM	67.8	68.3	67.9	68.0	***
79 B4	MUU	68.1	67.5	68.2	67.9	***
57 C1	FFM	68.9	67.0	68.0	67.8	*
88 C1	MFM	68.4	67.9	66 9	67.7	*
63 E1	MFU	67.4	65.9	67.3	66.9	*
70 C2	UFM	67.1	66.5	66.8	66.8	*
58 A4	MMM	68.4	64.2	67.4	66.7	*
59 C0	FMM	66.9	65.2	67.8	66.6	*
60 A4	UUU	68.4	65.3	64.8	66.1	***
63 E6	MUM	67.4	64.2	66.5	66.0	***
41 D1	UMU	66.9	66.2	65.4	66.2	***
41 D4	UUU	67.5	64.6	65.7	65.9	**
88 B4	MMM	67.0	62.4	66.8	65.4	*
91 A4	FUF	64.5	63.9	67.1	65.2	***
63 A4	FMF	65.7	65.3	63.6	64.9	*
70 C4	UMM	65.1	63.6	65.1	64.6	*
63 B4	FMU	66 0	63.4	64.1	64.5	**
44 A4	UMM	65.5	63.8	64.0	64.4	*
80 A2	MFM	64.3	64.0	64.7	64.3	*
20 B4	UMF	65.4	64.2	63.0	64.2	**
10 A4	FUU	64.6	63.1	64.0	63.9	****
26 B4	UUF	64.8	61.3	64.2	63.4	***
28 A4	MUM	64.3	62.5	63 1	63.3	**
10 B4	FMF	62.6	64.0	62.8	63.1	**
80 A4	MMM	62.3	61.6	62.5	62.1	*
65 B4	FMU	63.0	61.7	60.8	61.8	*

The temperature range for the entire group was as follows: Twelve apartments under 65.0 F., Sixteen apartments 65.1-67.9 F., Twelve apartments 68.0-69.6 F., Nine apartments 70.0-72.2 F.

Explanation of Auxiliary Heat Code:
3-19 observations of use of auxiliary heat.....*
20-29 " .....**
30-49 " .....***
50-and above " .....****

December 3, 1942, the coldest day of the test period:

20 *B2-UMF*, according to the average living room temperatures at 60 in. level had second highest average (71.8 F) for the test period. On December 3, 1942 the average living room temperature at 60 in. level was 71.3 and the average apartment temperature 64.1 F. The separate readings for the day averaged: morning 64.5 F; noon 63.3 F; and afternoon 64.5 F. It was observed at all three readings made on December 3 that the occupant was using auxiliary sources of heat. The occupant was wearing an average of 0.97 clo (insulation value of clothing), which is approximately 50 per cent above the amount required if sitting at rest in a room having normal thermal comfort temperature. The activity recorded was an average of 2.3 mets (body heat production). The occupant reported that she was uncomfortable two out of three visits.

63 *A2-FFF*, one of the two most favorable apartments in the entire study, (favorable boiler location, minimum exposed cold surfaces, and favorable sun orientation) had a living room air temperature average of 69.1 F at 60 in. level. The average living room temperature at 60 in. level on December 3 was 68.0 F and the average apartment temperature was 65.3 F; with morning, noon and afternoon temperatures 67.1 F, 66.0 F and 63.9 F respectively. No use of auxiliary heat was observed during the day's visits, but sun was observed at the noon visit. The occupant of this apartment was not at home during the first two visits but, with a clothing insulation of 1 clo and activity observed as 1 met, she reported that she was uncomfortable at the afternoon reading (4-6 p. m.).

60 *A4-UUU*, one of the most unfavorable apartments in the group studied, (unfavorable boiler location, large amount of exposed surface, unfavorable location for sunshine) had an average living room temperature (60 in. level) of 66.1 F for the entire study. The average living room temperature at 60 in. level for December 3 was 66.0 F, and the average apartment temperature 63.1 F. The afternoon reading average went down to 59.9 F; the noon to 61.5 F; with the morning average (66.4 F), the only one reaching the 65.0 F temperature range. Auxiliary sources of heat were being used at the time of the first two readings. The occupant's clothing at these readings averaged 0.6 clo and activity 2 mets. She reported that she was comfortable at both visits.

Reduction of Temperature, Time and Space was the third method employed. This method combined the second method with reduction in heated space. It was proposed that the heat be cut off to all but one bedroom. At first it seemed the most promising method, but was discontinued because accurate information concerning the effects of reduced space on oil consumption and air temperatures in the living portion of the apartment could not be secured due to the failure of the residents to cooperate completely when this method was being used. For these reasons

the original scheme of comparing three different methods of saving fuel had to be abandoned in favor of the only method (reduced time) which was found practical for this test. In this method the steam was cut off from all radiators in the middle of the day. The original method called for turning off the heat between 11:00 a. m. and 3:00 p. m., but this method was modified depending upon the temperature of the outdoor air. It is believed that the third method would prove very successful wherever radiation could be turned off, as planned, and doors to the unheated space kept closed.

10 *A4-FUU*, favorable boiler location, but unfavorable as to exposed surfaces and sunshine, had an average living room temperature (60 in. level) of 63.9 F for the entire study. The general average for the entire apartment on December 3, 1942 was 55.0 F, and the living room average at 60 in. level was 59.0 F. At none of the three readings for the day did the average of readings reach even 60.0 F. The averages for the day were: morning readings 56.9 F; noon 56.6 F; and afternoon 52.5 F. The temperatures in this apartment were this low in spite of the constant use of auxiliary heat during the day. The occupant was not at home for the afternoon readings, but at each of the others she reported that she was uncomfortable. Her clothing was observed as 1 clo and her activity as 2 mets at each visit.

Fuel Consumption and Weather Bureau Data

The Weather Bureau uses certain terms which are important in understanding fuel oil rationing. The daily mean temperature is the arithmetical average of the daily maximum and minimum temperatures, and the number of degree-days per day is the difference between 65 F and the daily mean temperature, when the latter is less than 65 F. For example, on November 28, 1942 the maximum temperature recorded at New York (Battery Place) station was 41 F, the minimum 27 F, the mean 34 F, and there were 65 minus 34 or 31 degree-days reported for this day.

The usual method of estimating probable fuel consumption during a heating season is to assume that the seasonal fuel consumption is directly proportional to the degree-days in that season. Although this method gives fairly satisfactory results for a season, it does not give as accurate results when trying to estimate fuel consumption for a single day. There are a number of reasons for this lack of accuracy; for example 65 F is not the true mean daily temperature of the indoor air in most cases; the Weather Bureau daily mean outdoor temperature is not the true hourly average temperature; and the degree-day method does not allow for the varying daily effects of wind velocity and hours of sunshine, each of which is an important variable. The actual quantity of heat lost from a structure per degree-day is appreciably greater on a day when there is little or no sunshine and a high wind velocity than it is on a sunny, calm day.

A modified degree-day method, creating a 70 F base degree-day, was followed in this study. The basic procedure was to burn two-thirds of the normal fuel oil on each day of the test in each building unit. The determination of the normal consumption for space heating was based upon the modified degree-day method used for the test. A study of the fuel oil consumption in all units during 1939, 1940 and 1941 showed that the oil used for space heating per 65 F base degree-day was not very constant. By adding 5 to each degree-day per day, the 65 F base degree-day may be transformed into a 70 F base degree-day. The oil used for space heating at Hillside per 70 F base degree-day was more nearly constant than per 65 F base degree-day, as shown in Table 5. The explanation of this result is that the mean indoor air temperature for apartments is known to be nearer 70 F than 65 F and furthermore, outdoor air temperatures at Hillside observed and averaged for 9 days of the test period, were 1.2 F lower than those reported by the Weather Bureau (Battery Place) at 9 a. m., and 1.0 F lower at 4:20 p. m., as given in Table 8. These effects both tend to make the daily fuel oil consumption more nearly proportional to the difference between 70 F and the Weather Bureau mean daily temperature of the outdoor air.

The daily test allowance for fuel oil for hot water heating was based on the average July consumption during 1939, 1940 and 1941 with a one-third cut.

For space heating, the allowance of oil was established for each unit so that there would be a one-third saving of fuel on the 70 F base degree-day. For example, Building Unit 1 was allowed 18 gal per 70 F base degree-day, a cut of one-third on the average consumption for the past three years of 27 gal.

During the actual tests, there was some husbanding of fuel oil, so that there was a saving of more than one-third on fuel. This was done by the operating staff in order that more fuel might be burned in colder weather.

The consumption of fuel oil, gas, and electricity in these apartments from November 1941 through February 1942, and November 1942 through February 1943, is given in Table 10 as supplied by the Hillside Housing Corp.

Use of Auxiliary Sources of Heat: Auxiliary sources of heat were used by the residents during the test, and the results obtained by the occupants of the three most unfavorable apartments are given in Table 11. It shows that as auxiliary sources of heat were increasingly used by these occupants higher living room temperatures at 60 in. level were recorded by observers; and that the *yes* response of the comfort vote was accordingly higher. Apartment 60 A1, using auxiliary heat almost constantly, increased the average living room temperature at 60 in. level from 4.4 to 4.6 F above that of 60 A4 and 41 D4 respectively, which did not use auxiliary heat to the same extent.

Effects of Apartment Location and Exposure Upon Air Temperatures: Examples from temperature readings taken in apartments selected to show the effects of distance from boiler, extent of cold surface, and sunshine upon the room air temperatures are shown in Table 12. In this table, the temperatures observed at 60 in. level in the living rooms of these apartments (all located in the same building unit) are compared for two specific days and averaged for the complete test period. On the days of November 22 and November 28, the living room temperatures are given for the morning period (readings taken between 9 a. m. and 11 a. m.), noon period (12:30 p. m. to 2:30 p. m.), afternoon period (4 p. m. to 6 p. m.),

Table 5—Oil consumption for space heating in Hillside Homes (Data for years 1939, 1940, 1941)

RANGE OF CONSUMPTION IN GALLONS PER DEGREE-DAY
BUILDING UNIT 1

Month	65 F Base Degree-Day 1939-40	65 F Base Degree-Day 1940-41	70 F Base Degree-Day 1939-40	70 F Base Degree-Day 1940-41
January	27.57	30.38	24.50	26.35
February	28.16	31.89	24.37	27.76
March	30.06	32.32	25.78	27.61
April	34.18	41.42	27.07	28.77
October	39.12	44.61	22.41	29.18
November	30.46	37.07	24.38	28.25
December	28.61	31.62	24.13	26.54
Reasonable Average	33.4		27.0	
Base Value, 1/3 Fuel Cut	.....		18.0	

ALL UNITS

	65 F Base Degree-Day	70 F Base Degree-Day
Reasonable Average	30.9	24.7
Base Value, 1/3 Fuel Cut	.....	16.5

Table 6—Fuel oil consumption and computed savings over normal use

Date 1942	UNIT I One-third Fuel Ration	UNIT I Gallons Used	UNIT I Percentage Savings
Nov. 16	524	492	37
17	416	502	20
18	308	280	39
19	308	390	15
20	254	302	20
21	452	352	48
22*	668	668	33
23	640	572	41
24	552	495	40
25	506	498	35
26*	416	558	11
27	614	505	45
28	740	668	40
29*	632	572	39
30	596	572	36
Dec. 1	506	558	27
2	704	602	43
3	931	688	51
4	886	750	43
5	777	850	27
6*	704	585	45
7	704	608	43
8	740	645	42
9	740	652	41
10	759	675	41
11	687	540	47
12	632	550	42
13*	777	480	59
Total for Unit 1	17,173	15,609	39.5
Total for ALL UNITS	80,162	69,709	42

*Sundays or Holidays.

Table 7—Weather Bureau data for test period (November and December, 1942)

Date	Avg. Vel. mph	Wind Dir.	Hours of Sunshine	Degree-Days (65F)	Mean Daily Temp.
Nov. 16	14.5	sw	9.5	19	46
17	12.9	sw	9.6	13	52
18	16.5	nw	6.3	7	58
19	14.5	s-nw	9.0	7	58
20	21.2	w	6.8	4	61
21	16.0	n	1.0	15	50
22	11.7	n	9.1	27	38
23	5.9	e	0.6	26	39
24	15.1	ne	0.0	20	45
25	20.0	n	0.0	18	47
26	9.3	nw	2.9	13	52
27	22.2	nw	8.5	24	41
28	20.1	w	8.8	31	34
29	15.6	w	2.0	25	40
30	13.7	w	8.4	23	42
Dec. 1	16.4	e	0.0	18	47
2	39.5	w	6.2	29	36
3	33.7	w	9.4	41	24
4	24.4	w	9.4	39	26
5	21.2	w	7.1	33	32
6	18.3	nw	9.4	29	36
7	16.1	nw	7.2	29	36
8	9.6	n	9.3	31	34
9	10.3	n	0.0	31	34
10	6.6	w	0.0	32	33
11	7.0	w	0.0	28	37
12	11.5	w	7.3	25	40
13	24.4	nw	2.4	33	32

Table 8—Comparison[a] of outside temperatures at Hillside versus Weather Bureau temperatures (Nine days at beginning of test period)

1942 Nov.	Daily Temperature 9:00 a. m. Weather Bureau	9:00 a. m. Hillside	4:20 p. m. Weather Bureau	4:20 p. m. Hillside
16	39	38	57	53
17	42	40	57	58
18	57	56	62	62
19	57	57	66	63
20	52	54	68	68
21	61	64	47	47
22	32	31	32	32
23	37	32	39	37
24	46	40	50	48
AVERAGE	47.0	45.8	53.0	52.0

[a]Taken by project engineer, outside his apartment.

and for the average of these three readings. These days were selected because of the low outside air temperature and large number of hours of sunshine. Auxiliary sources of heat within the apartment at the time the temperatures were read are noted in the table. The averages of 84 readings of the daytime temperatures at the 60 in. level in the living room in these apartments for the entire test are included. The comfort vote and use of auxiliary heat for the two days and the entire study are also given.

In comparing these results, when apartment *UUU* is compared with *MUU*, the effect of distance from the boiler is shown, since the first apartment was near the end of the steam supply line and the second one was in the mid-group. The difference between the average daytime temperatures in the living room of these two apartments at 60 in. level was 4 F on November 22, 1 F on November 28, and 1.8 F for the entire test period. The comfort vote for both apartments for these two days was positive except for apartment *UUU* on noon of November 28. However a wide difference is shown when the comfort vote for the entire test period is considered: Apartment *UUU* has 36 *Yes* votes while *MUU* has a total of 47.

When apartment *UMM* is compared with *UFM*, the effects of different extents of cold surfaces may be shown. The average temperature of the more exposed apartment was 2 F lower on November 22 and 8 F lower on November 28. For the entire test period, the more exposed apartment had a 6.5 F lower average living room temperature than the less exposed one. Little difference was shown in the comfort vote for these two apartments on November 22 and 28, but the comfort vote for the 28 days of the test period showed that the occupant of *UMM*, which had a greater extent of cold surface exposure, said she was comfortable only 29 times, while the occupant of *UFM* answered *yes* 47 times to the comfort vote question.

By comparing apartment *MMM* with *MMF*, the effect of sunshine is illustrated, because the solar orientation of *MMF* is more favorable than that of *MMM*. The difference between the average temperature of the sunlit apartment and that of the partially shaded apartment was 4 F on November 22, 1 F on November 28, and 2 F for the entire test period. This temperature difference is particularly noticeable in the noon observation when, on November 22, the temperature difference was 6 F. For the entire period the occupant of *MMM* said she was comfortable 54 times and uncomfortable 25 times; while the occupant of *MMF* said she was comfortable 63 times and uncomfortable only 15 times.

By comparing apartment *UUU* with *MMF*, the difference between a completely unfavorable and a generally favorable location is clearly shown. The difference between the average temperature in the living room of *MMF* and *UUU* was 6 F on November 22, 4 F on November 28, and 5.1 F for the entire test period. This is particularly striking when it is noted that auxiliary sources of heat were in use at practically all hours in *UUU* on November 28, while no auxiliary heat was used in *MMF* on the same day. Table 12 shows a striking contrast in the comfort vote for these two apartments. The occupant of apartment *UUU* with the most unfavorable location and exposure said she was comfortable 36 times during the test period; while the occupant of *MMF*, a more favorable apartment, said she was comfortable 63 times in response to the comfort question. It should also be noted that apartment *UUU* constantly used auxiliary heat sources during the entire test period.

One might conclude that it would have been possible, originally, to install more radiation in the least favored apartments, or to zone groups of apartments with similar exposure and heat losses. The fact is that the buildings studied are quite typical of heating practice, and with fuel rationing, these same effects will undoubtedly be observed in other buildings where, due to overheating in the past, they have not shown up before. Daily changes in wind direction and velocity and in the number of hours of sunshine further upset any attempt to maintain precisely the same air temperatures in all apartments at all times. Fuel rationing definitely limits the *open window* type of control so frequently used in the past and the inescapable conclusion from these test results is that the residents must make considerable adjustments in

Table 9—Increased cost of gas and electricity for auxiliary heat—November, 1942, through February, 1943, as supplied by the Hillside Housing Corp.

	GAS Winter of 1941-42	GAS Winter of 1942-43	GAS Increased Cost	ELECTRICITY Winter of 1941-42	ELECTRICITY Winter of 1942-43	ELECTRICITY Increased Cost
November	$ 931.21	$1,268.26	$ 337.05	$3,057.21	$3,415.00	$ 357.79
December	1,069.09	1,655.57	586.48	3,403.47	4,510.25	1,106.78
January	1,011.76	1,635.76	624.00	3,287.17	4,950.86	1,663.69
February	973.60	1,547.77	574.17	3,105.99	4,782.79	1,676.80
Total			$2,120.70			$4,805.06
Grand Total Gas and Electricity						$6,925.76

In this connection it should be noted that there were 464 Weather Bureau degree-days in New York City in November, 1941, and 555 degree-days in 1942.

Table 10—Consumption of fuel oil, gas, and electricity from November, 1941, through February, 1942, and November, 1942, through February, 1943

Winter	FUEL OIL Gal. per Apartment 1941-42	1942-43	GAS Cu Ft per Apartment 1941-42	1942-43	ELECTRICITY Kwhr per Apartment 1941-42	1942-43
November	71.0	42.9	1,158	1,766	131.3	152.8
December	95.3	63.3	1,374	2,546	164.3	233.3
January	116.0	64.0	1,285	2,506	149.9	268.9
February	107.4	55.3	1,224	2,322	131.3	233.9
Total per Apt.	389.7	225.5	5,041	9,140	576.8	889.0

Table 11—Use of auxiliary sources of heat

Apartment Code	Exposure Code	Auxiliary† Heat	Record Lowest Temperature for Entire Test	Average 60 in. Living Room for Entire Test	Comfort Vote Yes	Comfort Vote No
60 A1	UUU	****	60 in. B.R. 55 F (Gas oven in Kitchen)	70.5 F	57	18
60 A4	UUU	***	60 in. B.R. 56 F (Gas stove burner in Kitchen)	66.1 F	46	13
41 D4	UUU	**	30 in. B.R. 49 F (No heat)	65.9 F	40	31

†See footnote Table 4.

clothing worn to secure equal comfort in apartments where lowered air temperatures will certainly exist.

Clothing Adjustments Made by Tenants to Low Room Air Temperatures: Table 13 gives the clothing practices and adjustments of 45 families. This information was secured toward the end of the study after the families had experienced the discomforts of the lowered temperatures resulting from fuel oil rationing and had had an opportunity to make the adjustments they felt necessary for physical comfort.

Table 13 shows that in the 45 families, 42 women and 25 men made adjustments in their daytime clothing because of lower air temperatures in the apartments due to fuel oil rationing. Twenty-four women added warmer clothing, including slacks, warmer dresses, wool snuggies, part-wool undershirt, heavier housecoats or bathrobes, etc.; while 18 added sweaters only. Sixteen men added sweaters only and 9 men added long underwear or wool shirts and warmer bathrobes in addition to the sweaters. Thirty-three women and 16 men made adjustments in their sleeping garments. Twenty-seven women added flannel sleeping garments, 5 added extra top or warm bed jackets, and 1 slept in bathrobe over her sleeping garment when the weather was very cold. Fourteen men added flannel sleeping pajamas, 1 man adopted cotton pajamas (wearing pajamas for the first time), and 1 man wore an undershirt under his cotton pajamas.

Table 14 shows that when the apartment was over 72 F 90 per cent of the occupants in the sample group considered it warm enough and that when the temperature was between 68 F and 72 F, 81 per cent still felt comfortably warm. When, however, the room temperature was under 68 F only 46 per cent of the occupants considered the temperature comfortably high.

When the sensations of comfort of the occupants were compared with the clothing worn, results were obtained which at first seemed puzzling. More or less uniformly, the persons wearing light clothing expressed themselves as better satisfied than those who had put on heavy clothing. When such subjective reactions are obtained they rarely apply to the exact status of the subject at a given moment, but reflect his general appraisal of the total situation. It seems obvious that those who added extra protective clothing to their ordinary wearing apparel were those who are consistently *cold-blooded*, and the emotional reaction of such individuals toward a situation which had compelled them to change their habits may naturally be expected to be unfavorable.

All in all, it is obvious that:

1. These tenants were definitely uncomfortable at temperatures under 68 F.

2. Certain individuals reacted to this situation by wearing additional protective clothing, but this practice was apparently followed only by those who were most sensitive to low temperature, and that protection was not increased to a sufficient degree to make the low temperature conditions tolerable. Clearly some individuals can endure low temperatures even in their ordinary clothing without serious discomfort while others are more sensitive and feel dissatisfied even after they have modified to some extent their normal clothing habits.

Clothing Weights for Special Group of Families: A group of 12 families were selected from which data of special interest could be obtained in regard to the efforts of the occupants to meet low temperatures by wearing additional clothing. They were provided with scales and each night when undressing for bed all the daytime clothing, worn at the time, was weighed and the weight recorded (always exclusive of shoes). This was done for each member of the family. These data are of special interest since it is known that the protective value of clothing can be roughly estimated by its weight. On November 22, when the temperatures of the apartments averaged 69 F, the average weight of clothing worn by the men was 3 lb 6 oz and the weight of the clothing for the women was 1 lb 12 oz. On the coldest day of the study, December 3, the weight of the clothing for men had risen to 3 lb 9 oz

Table 12—Daytime temperature of living room at 60 in. level (Sample group of apartments)

Apartment Code and Exposure Code		*UUU* 60 A4	*MUU* 79 B4	*UMM* 44 A4	*UFM* 44 A1	*MMM* 79 B2	*MMF* 79 A1
Nov. 22, 1942							
A. M. Reading		68	70[a]	68	72	71	72[a]
Noon Reading		67[a]	75	70	73	70	76[a]
P. M. Reading		69	70	68	68	69	74
Average for Day 60 in. L. R.		68	72	69	71	70	74
Day's Average All Temp. in Apt.		66.4	67.3	64.9	69.2	69.2	71.3
Comfort Vote	Yes	A.M. N.	A.M. N.	N. A.M.[b]	A.M. N.	A.M. N.	N. P.M.
	No	P.M.[b]	P.M.[b]	P.M.[b]	P.M.[b]	P.M.	A.M.
Nov. 28, 1942							
A. M. Reading		66[a]	69	66	74	71	71
Noon Reading		66[a]	70	66	74	72	73
P. M. Reading		70[a]	64	62	70	68	69
Average for Day 60 in. L. R.		67	67	65	73	70	71
Day's Average All Temp. in Apt.		65.5	66.4	64	70.6	68.8	66.8
Comfort Vote	Yes	A.M. P.M.	A.M. N[b]	A.M. P.M. N.	N. A.M.	A.M. N.	A.M. N.
	No	N.			P.M.	P.M.	[b]
Lowest Temp. Observed During Test		56 F ‖	54 F ‖	52 F §	57 F †	54 F §	60 F § ‖
Highest Temp. Observed During Test		73 F ‡ § ‖	75 F ‡	72 F ‡	77 F ‡	73 F ‡	76 F ‡
Average 84 Readings for 28 Days of Test		66.1	67.9	64.4	70.9	69.2	71.2
Comfort Votes for 28 Days of Test	Yes	47	36	29	44	54	63
	No	13	28	19	34	25	15

[a]Auxiliary Heat. [b]Not Home or Don't Know. † = L. R. 30 in. ‡ = L. R. 60 in. § = B. R. 30 in. ‖ = B. R. 60 in.

Table 13—Clothing practices and adjustments

Waking Hours Adjustments Description	Men	Women
No change	8	3
Added sweater or jacket, only	16	18
Wore slack suit, heavier dress, wool snuggies, heavier housecoat or bathrobe, undershirt or flannel shirt, or jacket or sweater	0	24
Added sweater and long underwear or wool shirt or bathrobe (men)	9	0
No information	12	0
TOTAL NUMBER MAKING ADJUSTMENTS	25	42
TOTAL NUMBER MAKING *NO* ADJUSTMENTS	8	3

Sleeping Adjustments Description	Men	Women
No change	29	12
Extra top or bed jacket, only	0	5
Wore pajamas for the first time	1	0
Wore flannel sleeping garments	14	27
Wore undershirt under pajamas	1	0
Wore bathrobe over sleeping garments when very cold	0	1
No information	0	0
TOTAL NUMBER MAKING ADJUSTMENTS	16	33
TOTAL NUMBER MAKING *NO* ADJUSTMENTS	29	12

and that of the women to 2 lb 2 oz. The observers noted that the children were generally more warmly dressed than the parents.

Table 15 shows, in sample group of families, the general relation between the type of clothing worn and room temperatures. It will be noted that when the room temperature was over 72 F, 70 per cent of the occupants wore light clothing, 23 per cent medium weight clothing, and 7 per cent heavy weight clothing. When, on the other hand, the temperature of the room was under 68 F, only 24 per cent of the occupants wore light clothing, 55 per cent medium weight clothing, and 21 per cent heavy weight clothing.

Protection by Use of Heavier Clothing: Thermal comfort, at an assumed optimal skin temperature, involves three factors: rate of heat production of the body (dependent on the degree of muscular activity); the insulation value of the clothing worn; and the environmental temperature.

The terms *met* and *clo*, indicating body heat production and insulation value of clothing, respectively, were developed at the John B. Pierce Laboratory of Hygiene, New Haven, Conn. Briefly, *met*, the thermal activity unit, is approximately the heat produced by a subject resting in a sitting position under conditions of thermal comfort. One *met* varies in absolute amount with the size of the individual. For a man of average size it is approximately equivalent to the heat generated by a 100-watt lamp. *Clo*, the unit for thermal insulation value of clothing, is logically the amount of clothing insulation necessary to maintain in comfort a sitting-resting subject, activity 1 *met*, in a normally ventilated room (air movement 20 fpm or 10 cm/sec) at a temperature of 70 F and a humidity of less than 50 per cent.

One *clo* of clothing insulation permits the temperature to be dropped about 12 deg from the 83 F to 85 F level that is comfortable when at rest nude. The protective value of an ordinary light-weight man's suit is approximately 1 *clo;* the average woman's clothing, indoors, has the insulation value of ½ *clo*, which accounts for the fact that women prefer a temperature about 5 deg warmer than that preferred by the clothed man.

These terms were used during the study. The field workers recorded their observation of the housewife's clothing in *clo* and her activity in *mets*, at the time of each visit. Table 16 shows how these were employed in interpreting the comfort vote.

Table 16 shows the adjustment of two cooperators to varying temperatures. The average daily *clo* for these two cooperators for selected days of the test indicates that as the mean daily temperature (Weather Bureau) decreased the cooperators added more clothing; and that the tendency seemed to be to continue wearing the added clothing for two or three days afterward, even when the mean daily temperature (Weather Bureau) showed a rise of as much as 8 F.

On November 18, 19 and 20 (the three warmest days of the test period) and on November 29, 30 and December 1, when the mean daily temperature (outdoor) ranged from 61 F to 47 F, cooperator 80 A4—*MMM* used clothing insulation that varied from 0.5 to 0.87 *clo;* but on December 2 when the mean daily temperature dropped to 36 F the *clo* value went to 0.95. On December 3, the coldest day of the test period, the cooperator was wearing 1.1 *clo*, and was still wearing this amount of clothing on December 5 even though there had been a rise of 8 F in the mean daily temperature.

It is even more striking in the case of cooperator 28 A4—*MUM:* on December 3 she added clothing to total 1.2 *clo* and on December 5 the clothing observation was 1.5 *clo*. Observations recorded show that both occupants were almost consistently uncomfortable from November 29 through December 6. Daily temperature readings recorded for these days show that there is a variance of 0.1 F to 2.0 F between average living room temperatures at 60 in. level and average apartment temperatures, except on December 6 in 28 A4 when the living room average was 5.2 F higher. In three instances the living room temperature was lower.

Re-scheduled Activities as Result of Low Temperatures: In order to be more comfortable at lower temperatures, many residents reported that personal and family activities were re-scheduled. Chores requiring greater amount of physical activity, such as mopping kitchens or bathrooms, making beds, etc., were reserved for periods when heat was off during the middle of the day and early afternoon.

Hours for the family laundry were changed to coincide with the rationed hot water schedule, or in some cases the laundry was sent out because of the short period in which hot water was available. The ironing was done when there was little or no heat during the day or at night after the heat was turned off. Families having to send their laundry out complained of the additional cost.

In order to have auxiliary heat without wasting fuel, many families reported that they did more baking, roasting and broiling, and had more oven-baked meals since fuel rationing. Family bathing schedules had to be revised and much inconvenience was reported, especially where there were small children.

The social life of many families had to be reorganized. Some families reported having few or no callers and no social activities in the home, because friends found apartment too cold. One said that she kept all extra

Table 14—Relation of comfort sensation to room temperature (sample group of families)

	Room Temperature		
	73 F and over	68 F-72 F	67 F and under
Per Cent of Women Voting Apartment Warm Enough	90	81	46

Table 15—Relation of weight of clothing used to room temperature (sample group of families)

Type of Clothing Worn	Per Cent of Women Wearing Clothing of Each Type		
	73 F and over	68 F-72 F	67 F and under
Light	70	46	24
Medium	23	41	55
Heavy	7	13	21

wraps available when she had visitors. The kitchen in many apartments became the center for family and social activities.

Washing dishes was grouped into three classes—those who rushed to get the dishes washed before hot water was shut off, those who heated water for the purpose, and others who stacked all dishes, pots and pans until the water was hot in the evening.

There was a tendency among the residents to spend more time outdoors because of the low temperatures in the apartments. Children were kept out or permitted to stay out later in the afternoons.

The retiring time and rest periods of many families were affected by the fuel oil rationing program. Families went to bed earlier because of low temperatures. Some of the residents reported taking naps in the afternoon in order to keep warm.

General Conclusions

1. In these tests, the average of over 4,000 readings of the daytime temperature of the indoor air at the 60 in. level in the living rooms of 49 apartments was 66.7 F; there was a saving in fuel oil of 42 per cent but auxiliary sources of heat were used by the residents (See Tables 9 and 10); the average of the mean daily temperature of the outdoor air (Weather Bureau) for the 28 days of the test period was 41.1 F. The normal mean temperature for the heating season from October 1 to May 1 in New York City is 40.8 F. When the temperatures were read, the residents were asked if they were warm enough; out of 564 answers to the question on sampled days, 394 or 70 per cent answered *yes*.

It should not be concluded that a temperature of 66.7 F was maintained at all daytime hours in all apartment living rooms; or that this temperature could be maintained in the average apartment without the use of auxiliary sources of heat. In one apartment with average exposure, and located close to the boiler, selected as an illustration because observers found auxiliary heat being used only 6 times during 60 visits, the average temperature for all hours of the test period at the 60 in. level in the living room, obtained with a recording thermometer, was 63.9 F.

Unless considerably less than two-thirds of the normal consumption of oil is burned in mild weather it would not be possible to maintain daytime temperatures over 60 F in these apartments, or in other similar ones in New York City in the cold months of January (normal mean temperature 31.3 F) and February (normal mean temperature 31.2 F), without supplementing the oil ration with auxiliary sources of heat. It requires extremely good judgment, even a knowledge of the future, on the part of the operating staff to properly husband the allotment of oil.

2. Auxiliary heat sources used by residents, as observed by the field workers in a total of over 4,000 visits, included:

	Per cent of total visits
Electric heaters	12
Gas ovens	5
Gas stove burners	6
Hot water in bath tubs and wash tubs	3

The percentages shown do not include observations when the gas oven and top burners were on and apparently being used also for cooking purposes. Many housewives reported that they had adjusted their meal planning to include more oven-baked meals, baked desserts, baked breads, etc., so that some practical use could be made of the gas used for auxiliary heat.

On cold days, and in some of the colder apartments on average days, it was not unusual to find an electric heater, gas oven, and top burners of gas stoves all being used simultaneously as sources of auxiliary heat.

Gas and electricity were furnished for auxiliary heat without extra cost. The costs of these for the five units in November and December 1941 and January and February 1942, as compared with that of the same months in 1942 and 1943, are given in Table 9 as taken from the accounts of the Hillside Housing Corp. It shows the increased use of gas and electricity to provide auxiliary heat on the part of the tenant with its accompanying increased cost. The increased use of gas and electricity for auxiliary heat is shown in Table 10.

3. Before oil rationing went into effect, it was the practice in apartment houses to burn sufficient oil to keep the air temperature in the least favored apartment at a comfortable level. To adjust for inequalities in distance of apartment from boiler, extent of cold surface, and sunshine, each resident controlled the temperature in the more favored apartments by opening windows or in isolated cases by turning off radiators.

Now that oil rationing is in effect, the effects of distance from the boiler, extent of cold surface, and sunshine complicate the problem of resident control of air temperature, particularly if there is no zoning of the heating system.

With one-third less fuel oil, if the apartments near the boiler and with favorable exposure or orientation are kept at comfortable temperatures, it is inevitable that other less-favored apartments will be below comfortable air temperatures.

4. As a consequences of the storage of warm water in tubs, generally closed windows, and of the burning of large amounts of gas in the unvented stoves with the consequent formation of water vapor, the relative humidity in many of the apartments became so high that there was considerable condensation of water vapor on windows and even on the inside surfaces of exposed walls. The residents had to mop up water several times a day. This is a situation which may also occur in other apartments.

Table 16—Relation of clothing insulation and temperature

		NOVEMBER					DECEMBER				
		18	19	20	29	30	1	2	3	4	5	6
weather bureau data	Average Wind Vel-mph	16.5	14.5	21.2	15.6	13.7	16.4	39.5	32.7	24.4	21.2	18.3
	Direction	NW	S-NW	W	W	W	E	W	W	W	W	NW
	Hours of Sunshine	6.3	9.0	6.8	2.0	8.4	0.0	6.2	9.4	9.4	7.1	9.4
	Degree-Days 65 F.	7	7	4	25	23	18	29	41	39	33	29
	Mean Daily Temperature	58	58	61	40	42	47	36	24	26	32	36
80 A4—MMM	Average Temp. of Apartment	68.0	65.2	68.0	60.3	60.6	60.0	63.2	59.3	58.3	58.0	58.9
	Clothing Average in CLO	0.8	0.87	0.5	0.7	0.7	0.7	0.95	1.1	1.0	1.1	0.77
	Activity Average in METS	1.3	2.3	2.0	1.7	5.0	2.0	2.5	1.7	2.0	2.3	2.3
	Auxiliary Heat at Readings 1.	yes	no	no	no	no	no	no	no	no	O-T.B.	no
	2.	sun	sun	sun	no	sun	no	no	O-T. B.	sun	no	sun
	3.	sun	sun	no	no	no	no	O [a]	no	no	no	no
	Comfort Vote. Yes	3	3	3	—	—	—	—	—	1	—	—
	Comfort Vote. No	—	—	—	3	?	1	2	3	2	3	3
28 A4—MUM	Average Temp. of Apartment	66.0	65.8	68.3	63.5	62.3	63.0	60.8	55.5	57.0	61.7	60.3
	Clothing Average in CLO	0.58	0.75	....	0.9	1.1	0.8	1.0	1.2	1.4	1.5	0.8
	Activity Average in METS	1.5	2.0	....	1.3	1.7	2.3	1.5	2.0	2.0	3.0	2.3
	Auxiliary Heat at Readings 1.	no	no	no	T.B.[a]	O.	O.	H.W.	T.B.	T.B.	N.H.	O.
	2.	no	no	no	no	T.B.	T.B.	no	T.B.	N.H.	T.B.	E.H.
	3.	no	no	no	T.B.	no	no	N.H.	T.B.	T.B.	T.B.	E.H.&T.B.
	Comfort Vote. Yes	—	1	—	1	—	—	1	—	—	1	—
	Comfort Vote. No	2	1	—	2	3	3	1	3	2	1	3

[a]Symbols. O = Gas Oven. T.B. = Top Burners; H.W. = Hot Water in Tubs. E.H. = Electric Heater. N.H. = Not Home.

Final Values of the Interaction Constant for Moist Air

Third progress report of research sponsored by the American Society of Heating and Ventilating Engineers in cooperation with the Towne Scientific School, University of Pennsylvania.

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SUMMARY—Final values of the interaction constant for moist air are reported. These values are proposed as definitive for the range 0 to 30 C. Remarkable agreement with the predictions of modern quantum statistical mechanics justifies the use of the theory to extrapolate well outside the experimental range. It will then be possible to compute the various thermodynamic properties of moist air, including volume, enthalpy and entropy for all temperatures and pressures of practical interest. It is hoped that the resulting formulation will be acceptable as standard

Introduction

THIS PAPER reports final values of the interaction constant for moist air for the range 5 to 25 C as determined experimentally in a cooperative investigation between the Towne Scientific School, University of Pennsylvania, and the American Society of Heating and Ventilating Engineers through its Research Technical Advisory Committee on Psychrometry. The ultimate objective of the investigation is a formulation of the thermodynamic properties of moist air which, on account of accuracy and thermodynamic consistency, can claim universal acceptance as standard. To accomplish this objective requires first of all to measure a certain temperature function, called the interaction constant, reliable values of which have hitherto been unknown.

A preliminary value of the interaction constant for 15 C was reported in a previous paper.[1] This preliminary value was much smaller than had been anticipated in designing the apparatus for its measurement so that the allowed errors in individual measurements did not yield a sufficiently small probable error in the final result. It became clear, therefore, that the apparatus itself and the technique of operating it required further study with a view toward improving the reliability of individual measurements. Furthermore, it was necessary to make measurements at other temperatures in the range of interest to the air conditioning engineer. The improved reliability and extension to cover the range 5 to 25 C have now been accomplished.

Although the interaction constant is defined in Chapter 1, Heating, Ventilating, Air Conditioning Guide 1943, and although the theory of the experiment devised for its measurement has been explained in the Preliminary Report referred to, it seems desirable to review these matters briefly here.

The Interaction Constant

Statistical mechanics predicts that for a mixture of two individual gases, the relation between pressure P, specific volume v, and temperature T, valid at sufficiently low pressures, is

$$Pv = RT - [A_{aa}x^2 + 2A_{aw}\,x\,(1-x) + A_{ww}\,(1-x)^2]P \quad \ldots\ldots(1)$$

where the subscripts have been chosen with reference to moist air as a mixture of dry air (subscript a) and water vapor (subscript w) in mind. In this case x would denote the molfraction of the dry air. In the special case $x = 0$, the mixture consists of water vapor alone and only the term A_{ww} remains as coefficient of the pressure in the righthand member. This term is called the *second virial coefficient* of water vapor. It expresses the effect of intermolecular forces between pairs of like water molecules and is supposed to depend only on the temperature. Similarly A_{aa} denotes the second virial coefficient of dry air. Reliable values of A_{aa} and A_{ww} are available in the literature.

Complete and accurate information regarding dry air and water vapor separately cannot be made to yield complete and accurate information regarding mixtures of these two constituents; for superimposed on the forces between pairs of *like* molecules are the forces of interaction between pairs of *unlike* molecules. The effect of these interaction forces on the relation between pressure, specific volume, and temperature in the case of moist air is given by the coefficient A_{aw} called the *interaction constant*. It too is supposed to be a pure temperature function (not actually a constant) and its measurement is the immediate objective of the cooperative investigation being reported.

The Saturation-Isotherm Experiment

The experiment devised for the measurement of the interaction constant A_{aw} is referred to as a saturation-isotherm experiment. A steady stream of dry, carbon dioxide-free air is passed over liquid water in a suitable saturator and made to leave, *presumably saturated*, at measured pressure p and measured temperature T. It then passes through suitable dryers in which the water added in the saturator is removed and collected. Now the equation for saturation can be derived from Equation (1) by applying well-known identical relations of thermodynamics, except that certain information from the literature must be added as follows: (*a*) the vapor pressure of pure water, a function of temperature only, p_s; (*b*) Henry's constant expressing the extent to which air dissolves in liquid (or solid) water, regarded as a pure temperature function, k; (*c*) the specific volume of liquid (or solid) water regarded as depending only on temperature, v'_w. Details of the calculation are given in the Preliminary Report and only the final result will be repeated here, namely,

$$\log_e\left[\frac{(1-x)\,P}{p_s}\right] = A\left(\frac{P}{p_s} - 1\right) - B(1-\lambda)\left(\frac{P}{p_s} - 2 + \frac{p_s}{P}\right) \quad \ldots\ldots(2)$$

where

$$A = kp_s + \frac{v'_w p_s}{RT} + \frac{A_{ww}p_s}{RT}$$

$$B = \frac{A_{aa}p_s}{RT} + \frac{A_{ww}p_s}{RT}$$

$$\lambda = \frac{2A_{aw}}{A_{aa} + A_{ww}}$$

The parameter λ is obviously a pure temperature function if A_{aa}, A_{aw}, A_{ww} themselves depend only on temperature as predicted by statistical

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[1] ASHVE Research Report No. 1186—The Interaction Constant for Moist Air, by John A. Goff and A. C. Bates. (ASHVE Transactions, Vol. 47, 1941.)

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mechanics. The name *interaction constant* can be used alternatively for λ and A_{ww} without risk of serious confusion.

The mol-fraction of water vapor $(1 - x)$ in the saturated mixture can be calculated if the weight of dry air passing through the apparatus during the same time that the water added in the saturator is later removed and collected in the dryer is determined. Then, since pressure P and temperature T are measured, there would remain only one unknown in Equation (1), namely, the interaction constant λ. But it was considered essential to avoid the necessity of weighing the dry air. Consequently it was arranged to return the dry air to a second saturator at lower pressure P_2, but same temperature T, and thence to a second dryer. The water added in the second saturator is collected over the same period of time as that in the first saturator; and since the same weight of dry air passes through both saturators during this time, this weight of dry air can be eliminated between two writings of Equation (2), one for the high pressure P_1 and the other for the low pressure P_2. This elimination makes possible the determination of λ without requiring to weigh the dry air; mathematically,

$$\lambda = \frac{\log_e \left(\frac{w_1 P_1}{w_2 P_2} \right)}{B(\pi_1 - \pi_2)\left(1 - \frac{1}{\pi_1 \pi_2}\right)} + 1 - \frac{A}{B\left(1 - \frac{1}{\pi_1 \pi_2}\right)} - \Delta\lambda \quad \ldots\ldots (3)$$

where

$$\Delta\lambda = \frac{\log_e \left(\frac{\left(1 + 1.60768 \frac{w_1}{w_a}\right)\left(1 - \frac{1}{\pi_1}\right)}{\left(1 + 1.60768 \frac{w_2}{w_a}\right)\left(1 - \frac{1}{\pi_2}\right)} \right)}{B(\pi_1 - \pi_2)\left(1 - \frac{1}{\pi_1 \pi_2}\right)}$$

and *where*

w_1 = weight of water collected after saturation at the high pressure P_1

w_2 = weight of water collected after saturation at the low pressure P_2

$\pi_1 = P_1/p_a$

$\pi_2 = P_2/p_a$

w_a = weight of dry air from which w_1 and w_2 are removed simultaneously.

1.60768 = ratio of molecular weight of water to that of dry, CO_2-free air

The fact that w_a remains in Equation (3) would appear to contradict the statement that this has been eliminated between two writings of Equation (2). Actually, however, no contradiction is involved. For, since $\Delta\lambda$ is a small corrective term, a tentative value of λ can be computed from Equation (3) ignoring it; this tentative value can be substituted into either writing of Equation (2) to calculate an approximate value of $(1 - x)$; and from it can be calculated an approximate value of w_a for the evaluation of $\Delta\lambda$ and the subsequent re-evaluation of λ itself.

Evidence of Complete Saturation

It is proposed to base calculations of the volume, enthalpy and entropy of moist air on the values of λ determined in the manner described. It is therefore important to adduce as much evidence as possible to show that these do not represent merely an empirical adjustment of Equation (2) to fit observed data. The most striking evidence on this point is presented under heading Interaction Constants in the form of a comparison between the measured values of λ and those predicted by quantum statistical mechanics. But the experimental part of the present investigation was practically completed before any such comparison was attempted; therefore, it seems appropriate to at first confine attention to the strictly experimental evidence.

In the first place, if λ is a pure temperature function as assumed in the derivation of Equation (2), then the same result should be obtained at a given temperature regardless of the pressure settings P_1 and P_2, regardless of the rate of flow through the apparatus for given pressure settings (within limits, of course), and regardless of whether saturation is approached by evaporation or condensation. Actually, the different elements of the apparatus were so critically matched that wide variations in these conditions would have introduced excessive uncertainties in the individual measurements and thereby have increased the probable error in the final result to the point of obscuring the evidence sought. Nevertheless, sufficiently wide variations to indicate the soundness of the method and the practical attainment of complete saturation were made.

In the second place, provision was made to weigh the dry air as a check on the satisfactory performance of the apparatus as a whole and as an additional check on the soundness of the method. It was explained in the preceding article how w_a could be eliminated between two writings of Equation (2), thus permitting the determination of λ without requiring to weigh the dry air. It was also explained that this value of λ could be substituted into either writing to calculate the *expected* weight of dry air passing through the apparatus during the time in which the two weights of water were collected in the dryers. The agreement between expected and directly measured weights of dry air was always so close that any slight discrepancy could be attributed entirely to uncertainty in the measurement of temperature ($\pm$ 0.02 C) or to uncertainty in the knowledge of the vapor pressure p_a, or both.

In view of the evidence briefly presented it seems safe to conclude that the complete saturation assumed in the derivation of Equation (2) was practically attained and that the measured values of λ are indeed those of the interaction constant contemplated in Equation (1).

Refinements

A tentative value of λ at 15 C, namely, 0.075 was given in the Preliminary Report; the final value reported now is substantially lower, namely, 0.048. This lowering is the direct result of various refinements of the apparatus and of the technique of operating it, which will now be discussed.

1. *Pressure Control:* The desirability of improving the pressure control was mentioned in the preliminary report. The source of air is a small oxygen bottle suspended from one arm of a sensitive balance. In order to limit the pressure in the take-off tube and keep it reasonably constant, a small reducing valve was mounted directly on the cylinder. This valve was arranged for pneumatic control by connecting the space on the control side of its diaphragm to a suitable reservoir filled with compressed air. The pressure in the reservoir could, of course, be raised or lowered by admitting or withdrawing air.

During test, the pressure in the supply bottle would drop from about 1500 to 200 lb/in.,[3] too wide a variation for a single valve to reduce to zero within a few thousandths of an inch of mercury as desired. Consequently a second reducing valve, mounted on the main control panel, was placed in series with the first one. But even the two valves in series permitted the pressure in the saturators to drift; hence some additional compensation was required. Shortly after obtaining the data reported in the Preliminary Report, one of the authors of that paper (A.C.B.) completed the construction of a device which provided the necessary additional compensation.

The device referred to consisted of a tall manometer connected to the delivery side of the first reducing valve and provided with a lamp and photocell on opposite sides of its mercury column at the desired level. If the mercury level should drop thus permitting light from the lamp to reach the photocell, this light would actuate the photocell to close a suitable relay and energize a resistance heater wound around the reservoir communicating with the control side of the reducing valve. The heat thus

added would raise the air pressure in the reservoir, increase the opening in the reducing valve, and restore the mercury level in the manometer to its original position. By means of this device, the delivery pressure from the first reducing valve could be regulated to within ± 0.15 in. Hg thus permitting the second valve to regulate the pressure in the saturator to within a few thousandths of an inch of mercury over periods as long as 9 hours. Additional compensation in the form of a manually operated resistance heater wound around the air reservoir communicating with the control side of the second reducing valve was provided; but only rarely was it found desirable to use it.

2. *Stirring Motors:* The stirring motors were originally mounted directly over the thermostats to which the main manometers were also attached. This made it possible for vibrations to be transmitted to the manometers to produce small standing waves on the mercury menisci. This source of error was easily removed by building a separate scaffold on which to mount the stirring motors so that vibrations were damped out in the concrete floor of the laboratory.

3. *Rocking the Saturators:* Originally it was thought necessary to rock the saturators slowly in order to flush all inside surfaces with water and thus aid complete saturation. But it was immediately discovered that rocking produced small pressure fluctuations which introduced uncertainty into the readings of the manometers. Fortunately, preliminary tests had indicated that rocking the saturators was an unnecessary precaution; hence it was stopped with the saturators carefully levelled.

4. *Meniscus Corrections:* With the uncertainties described in the measurement of pressure eliminated or considerably reduced, it became feasible to achieve further refinement by applying more accurate meniscus corrections. These were obtained from data in International Critical Tables.

5. *Thermal Expansion of Mercury and Scales:* The temperature correction for relative thermal expansion between the mercury and the steel scales of the manometers was recalculated from data in International Critical Tables. The coefficient used was 0.9478×10^{-4} (F^{-1}). All pressures were reduced to inches of mercury at 68 F, 980.196 cm/sec^2 (Philadelphia). During the later tests, the temperature was measured at several points along the mercury column in order to obtain a more reliable average value on which to base the correction for thermal expansion.

6. *More Frequent Readings:* In order to further increase the accuracy of pressure measurements, readings were taken at more frequent intervals than in the preliminary tests. Intervals of ten minutes were used in the shorter runs, 15 min in the longer ones, so that at least twenty separate readings were obtained in any one run. The average of all readings was used in the final calculation of λ by means of Equation (3).

Further Refinements

The refinements described in the preceding paragraph relate to the regulation and measurement of pressure. In this paragraph attention is turned to refinement in the collecting and weighing of the water removed by the dryers.

The drying agent used was anhydrone, $Mg\ (Cl\ O_4)_2$, contained in glass towers. Approximately 50 g (grams) of anhydrone was introduced into each tower by means of an apparatus especially designed to minimize contact with air during the filling operation. It was desired to determine the increase in weight to within ± 0.0005 g representing an accuracy of about one part in 100,000. The chief sources of error appeared to be buoyancy, variable conditions of the outside surfaces of the towers, and other effects produced by changes in atmospheric conditions.

1. *External Buoyancy:* This source of error was effectively eliminated by using as counterweight a sealed dummy tower similar in all respects to the main towers. This was possible since change in weight between beginning and end of test was the only thing of interest.

2. *Internal Buoyancy:* Due to the nature of the drying chemical and to the method of filling the towers, there was a considerable volume of air inside the towers. It was obviously important to account for any possible changes in the weight of this air between beginning and end of test. During weighing, a tower was necessarily open to atmosphere through a capillary tube; hence any change in atmospheric pressure between beginning and end of test (possibly 9 hours) would produce a change in the weight of air within the tower. This effect was over-looked in the preliminary tests but was compensated for in the final tests by unsealing the dummy tower for a short time before each weighing operation thus permitting it to make the same adjustment to atmospheric conditions as the main towers.

An additional internal buoyancy effect was produced by displacement of air from the towers by the water collected. This effect is difficult to determine accurately because the water is absorbed as water of crystallization and the exact hydrate formed is not definitely known. Assuming that $Mg\ (ClO_4)_2 \cdot 7\ H_2O$ is the hydrate formed, the buoyancy correction calculated from density data given in International Critical Tables was 0.0008 g per gram of water collected. Information regarding the densities of other possible hydrates is not very reliable; but the evidence is that the correction would not be materially altered.

3. *Surface Effects:* Deposition of moisture on the outside surface of a tower will produce an error in weighing unless precautions are taken to insure that similar deposition occurs on the dummy tower also. The various precautions include storing all towers in a dessicator when not being used or weighed, giving each tower a standard wiping with a clean rag before placing it in the balance case, keeping a dish of concentrated sulfuric acid inside the balance case, and allowing ample time (25 min) before each weighing for the new tower to come to equilibrium with the dummy tower inside the balance case. The tediousness of the weighing operation can be appreciated from these remarks.

4. *Other Effects:* Rapid temperature changes and temperature gradients in the neighborhood of the balance produce some convection currents inside the balance case. To thermostat the laboratory room was impracticable, but it was found possible to minimize these effects by periodically adjusting the opening of the door to the warmer laboratory adjoining.

Data from International Critical Tables indicate that approximately 4×10^{-4} milligrams of water per gram of air passes through the anhydrone. An attempt was made to obviate the necessity of applying this correction by using a P_2O_5 backing tower. But the weight of water collected in the backing tower turned out to be too small to measure accurately; hence the attempt was abandoned and the correction applied instead.

Optimum Operating Conditions

As a guide to the selection of optimum operating conditions, an approximate relation giving the error in λ produced by errors in the individual measurements was derived from Equation (3) as follows:

$$d\lambda = \frac{1}{B(\pi_1 - \pi_2)}\left[\frac{1.6(\pi_1 - 1)}{w_a}\,dw_1 + \frac{1.6(\pi_2 - 1)}{w_a}\,dw_2 + \frac{d\pi_1}{\pi_1 - 1} + \frac{d\pi_2}{\pi_2 - 1}\right] \quad (4)$$

where $d\lambda$, dw_1, etc., are respectively the *absolute* errors in λ, w_1, etc.

In all final tests P_2 was set at approximately 25 in. Hg, just enough below atmospheric pressure to insure that the stopcocks on the drying towers remained tight. A lower setting than necessary would not only invite leakage of air into the low pressure side of the system but would make small errors in the measurement of P_2 more significant in the evaluation of λ.

Having decided on a fixed value of P_2 it would appear from Equation (4) to be desirable to set P_1 as high as possible. However, with the existing apparatus it was not practicable to exceed about 80 in. Hg; hence a setting of approximately 75 in. Hg for P_1 was used in all final tests.

With the two pressure settings fixed, Equation (4) shows that the contributions to $d\lambda$ from small errors in w_1 and w_2 are minimized by selecting the largest possible value of w_a. In earlier tests, an upper limit on the value of w_a was set by the capacity of the supply cylinder from which the air was drawn. However, after having established close agreement between the expected and directly measured weights of dry air in a sufficient number of tests, this cross-check was discontinued and greater quantities of air drawn from the larger bottle were

used. The capacity of the dryers then fixed the upper limit on w_s.

Estimated Uncertainty in λ

Weighings were considered accurate to within ±0.0005 g. Each tower was weighed twice in each test. The possibility that the buoyancy, surface, and other effects discussed under heading Further Refinements were not perfectly compensated introduces some additional uncertainty into the measurement of water collected; however, it seems fair to assign to w_1 and w_2 an over-all uncertainty of ±0.0015 g per tower plus 10^{-4} milligrams per gram of air.

Uncertainty in the measurement of pressure arises from uncertainties in (*a*) reading the scales (±0.001 in.Hg), (*b*) correcting for thermal expansion (±0.0004 *P* in.Hg); (*c*) adjusting the scales (±0.002 in.Hg for earlier tests, ±0.001 in.Hg for later tests).

The estimated uncertainty of ±0.02 C in the measurement of temperature contributes practically no uncertainty to the determination of λ even though it does correspond to an uncertainty of as much as ±0.14 per cent in the saturation pressure, p_s. If this figure be increased to ±0.20 per cent to allow for the possibility that the values of p_s from the literature may be in error by as much as ±0.06 per cent, still the uncertainty in λ from both sources is at most ±0.0005. This emphasizes an important advantage of the two-stage experiment over a single-stage experiment requiring to weigh the dry air. In the latter, small uncertainties in the measurement of temperature and in the knowledge of vapor pressure would greatly reduce the accuracy of the calculated value of λ.

The uncertainty in the gas constant *R* is entirely negligible. That in the apparent molecular weight of dry, CO_2-free air may be estimated as ±0.01 per cent; but it contributes no appreciable uncertainty to the calculation of λ by the method of eliminating the weight of dry air. It is impossible to estimate closely the uncertainties in A_{aa}, A_{ww}, v'_w and *k*, all of which enter the calculation of λ. But assuming that the first three are in error by at most ±0.5 per cent and making a liberal allowance of ±10 per cent in *k*, the total contribution to uncertainty in λ is at most ±0.0003.

In allowing an uncertainty of as much as ±10 per cent in Henry's constant *k*, it was not intended to asperse available solubility data from which this constant is derived. Rather, this liberal allowance was made in recognition of the fact that *k* entered Equation (2) on certain simplifying assumptions. Similarly, the use of Dalton's Rule to eliminate mol-fraction *x* from the righthand member of Equation (2) represents an approximation which can be shown, however, not to contribute appreciable uncertainty to the calculated value of λ.

Summary of Results

The final values of λ are given in Table 1. The estimated uncertainties given in Column 4 are the sums of the separate contributions explained in the preceding article. In Column 5 are given values of the probable error of the mean (Column 2) as computed by the conventional method except that an allowance of ±0.001 for systematic errors in thermal data from the literature has been included. In computing the mean value of λ for a given temperature the values from individual tests were assigned different weights to favor those showing greatest internal consistency. The exact method of weighting need not be explained since if all tests had been assigned unit weight the final results would not have been altered materially.

The method of reducing the data of Pollitzer and Strebel[2] to obtain values of λ for comparison with those of the present investigation was explained in the Preliminary Report. It was not considered worthwhile to attempt to improve this method or to estimate the limits of uncertainty in the results. It may be, therefore, that the values listed in Table 1 for 50 and 70 C do not represent the best possible reduction of the Pollitzer and Strebel data; but they do afford valuable comparison.

Predictions from Statistical Mechanics

Statistical mechanics asserts that the second virial coefficient of a gas arises from forces between *pairs* of molecules, and that, in the aggregate, the force between any pair may be regarded as depending only on the distance of separation *r*. The existence of a force of this kind implies that the pair possesses potential energy $E(r)$. Statistical mechanics then proves that the relation between the second virial coefficient $A(T)$ and the potential energy $E(r)$ is the following.

$$A(T) = 2\pi N_o \int (e^{-E(r)/kT} - 1) r^2 dr \quad [5]$$

where

N_o = number of molecules per mol of gas (Avogadro's Number)
k = Boltzmann's Constant
r = distance of separation

Long-range Attractive Forces

Recent developments in quantum mechanics have made it possible to calculate the function $E(r)$, at any rate, the contribution to $E(r)$ arising from long-range attractive forces. In an interesting article entitled, *Van der Waals Forces*, Margenau[3] reviews the present state of these developments. He states that all through the period from the beginning to the end of the nineteenth century, investigators were convinced of the novelty and essential uniqueness of these long-range attractive forces, but that now these forces have been stripped of their uniqueness and shown to be of the nature of simple electric interactions.

Some molecules, notably the water molecule, possess what is called a *permanent dipole moment* due to a permanent asymmetric distribution of the electric charges of their constituent atoms. Averaged over all possible orientations, the force between two such rotating molecules would be exactly zero; hence, if no particular orientation were favored, there could be no resultant force. But, as a matter of fact, attractive orientations *are* favored because they minimize the potential energy of the pair for a given separation *r* and because, in the aggregate, the number of pairs having a given potential energy is larger the smaller this energy. This so-called *dipole alignment effect* contributes to $E(r)$ an amount proportional to $p_1^2 p_2^2 / r^6$ and inversely proportional to absolute temperature *T*. The dipole moments of the two molecules are denoted by p_1 and p_2, different subscripts being used to include the case of a pair of *unlike* molecules.

In the discussion of the dipole alignment effect no mention was made of the possibility that the distribution of electric charges within each member of a pair of molecules is actually deformed to some extent by the electric field surrounding the other molecule. This is the so-called *induction effect*

[2] Über den Einfluss indifferenter Gase auf die Sättigunge-Dampfkonzentration von Flussigkeiten, by F. Pollitzer and E. Strebel. (Zeit. fur Phys. Chemie, Vol. 110, 1924, pp. 768-785.)

[3] Van der Waals Forces, by H. Margenau. (Rev. Mod. Phys., Vol. 11, No. 1, January 1939, pp. 1-35.)

Table 1—Summary of Results

1 t (C)	2 λ (MEAN)	3 No. of Tests Used	4 Estimated Uncertainty	5 Probable Error of Mean	6 Authority
5	0.043	4	±0.003	±0.002	Goff, Andersen, Gratch
15	0.048	6	±0.003	±0.002	Goff, Andersen, Gratch
20	0.054	4	±0.005	±0.002	Goff, Andersen, Gratch
25	0.053	5	±0.005	±0.003	Goff, Andersen, Gratch
50	0.056	..	.....	.....	Pollitzer & Strebel
70	0.07	..	.....	.....	Pollitzer & Strebel

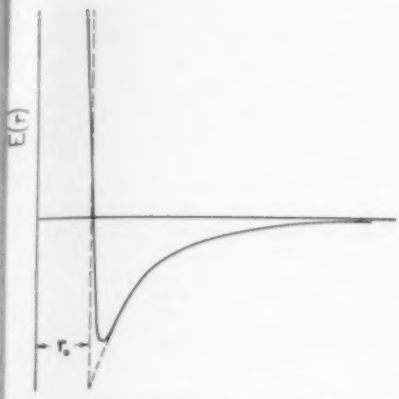


Fig. 1—Potential energy E (r)

and it makes an additional contribution to $E(r)$ of amount proportional to $(a_1 p_2^2 + a_2 p_1^2)/r^6$, where the a's denote the polarizabilities of the two molecules, different subscripts being used again to cover the case of unlike molecules. It should be noticed that the induction effect is not strongly temperature dependent as is the case with the alignment effect.

In analyzing the dipole alignment and the induction effects, the atoms were regarded as structureless points carrying electric charges. But a closer examination reveals the necessity of considering the fact that each atom consists of a nucleus surrounded by a deformable electron cloud. This means that each atom may become, if only momentarily, a dipole even though it has no permanent dipole moment. The possibility that each atom, and therefore each molecule composed of atoms, may have a temporary dipole moment generates an additional tendency toward alignment and produces, in an aggregate of molecules, the so-called *dispersion effect*. The contribution to $E(r)$ from these dispersion forces is, in the main, proportional to $f_1 f_2 / r^6$ where the f's are constants characteristic of the interacting molecules and are obtainable from information regarding their indices of refraction.

Margenau[4] points out that the distinction between the three effects described is really historical and that fundamentally all three spring from the same root. Each may contain terms in higher powers of the inverse distance, namely, r^{-8}, r^{-10}, etc. But, as an adequate approximation, the contribution to $E(r)$ from *all* long-range attractive forces may be written

$$E_a(r) = -\left(\frac{a_1}{T} + a_2 + a_3\right) r^{-6} - a_4 r^{-8} - a_5 r^{-10} \ldots\ldots\ldots (6)$$

Table 2 lists numerical values of the a's for gases of interest in the present paper. These values are computed from spectroscopic and other related information.

[4]Loc. Cit. See Note 3.

Short-range Repulsive Forces

It is well known that, for very small distances of separation r, the forces between molecules become strongly repulsive. The potential energy $E(r)$ must therefore rise rapidly with decreasing r. This means that there must be added to $E(r)$ as given by Equation (6) a positive term $E_s(r)$ representing the contribution from short-range repulsive forces. It appears to be possible to predict the form of this contribution from quantum mechanical considerations; but the prediction has not yet been worked out for any of the gases of interest here.

A practical way around the difficulty is suggested in Fig. 1. The true values of $E(r)$ are represented by the solid curve; but these can be replaced by the dotted curve which follows Equation (6) for values of $r > r_o$, but rises vertically to infinity at $r = r_o$. If the value of r_o is adjusted to make $A(T)$ calculated from Equation (5) agree with the observed value at a temperature near the middle of the range of interest, this agreement can reasonably be expected to hold for other temperatures not too far removed from the one in question.

Second Virial Coefficients

Details of the calculations will not be given in this paper, but the order of agreement between calculated and observed second virial coefficients for H_2, N_2 and dry air will be shown.

In the cases of H_2 and N_2, reliable information is available only at 0 C (Cragoe)[5]. At other temperatures there is disagreement of as much as 20 per cent between various investigators. The only comprehensive survey of existing data is that of Keyes[6] whose correlation, however, is unsatisfactory from the point of view of the theory outlined here. Since a discussion of the second virial coefficients of H_2 and N_2 is incidental to a comparison between observed and calculated values of the interaction constant for H_2-N_2 mixtures, and since the only observations available for this purpose are those of Verschoyle[7], it seems that to

[5]Slopes of the pv Isotherms of Some Thermometric Gases at Pressures Below Two Atmospheres, by C. S. Cragoe. (Temperature Symposium, American Institute of Physics, pp. 89-126.)

[6]Gas Thermometer Scale Corrections Based on an Objective Correlation of Available Data for Hydrogen, Helium and Nitrogen, by F. G. Keyes. (Temperature Symposium, American Institute of Physics, pp. 45-88.)

[7]Verschoyle, Proc. Roy. Soc. A, Vol. 111, 1926, p. 552.

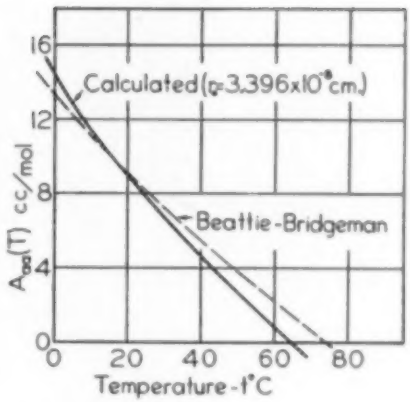


Fig. 2—Second virial coefficient for dry air

use his data exclusively will at least be a consistent procedure. These data may be in error by as much as 10 per cent, though probably less. Table 3 gives the desired comparison.

In the case of dry air, it would be necessary to calculate the second virial coefficients for all individual constituents plus the interaction constants for all unlike pairs to obtain the second virial coefficient of the mixture, if strict adherence to the theory were to be attempted. However, since the principal constituents are N_2 and O_2 and since the various coefficients in Table 2 for these gases do not differ widely, it becomes unnecessary to follow this elaborate procedure. Instead the coefficients for the mixture can be obtained as weighted averages of the corresponding coefficients for N_2 and O_2. The results are given in Row 5 of Table 2.

Fortunately, the observed data on the second virial coefficient of dry air are quite satisfactory. Fig. 2 shows the order of agreement obtained by adjusting $r_o = 3.396 \times 10^{-8}$ cm to give close agreement at 20 C. It is to be noticed that a constant value of r_o gives only fair agreement over the range —10 to 80 C. However, this particular range is an unfavorable one, because in it the second virial coefficient changes sign; and when this occurs, the calculations are very sensitive to changes in r_o. Allowing r_o to vary by as little as 1 per cent over this range would achieve perfect agreement with the Beattie-Bridgeman[8] data.

[8]A New Equation of State for Fluids, by J. A. Beattie and O. C. Bridgeman. (Proceedings American Academy Arts and Science, Vol. 63, 1928, p. 229.)

Table 2—Van Der Waals Force Constants

	Gas	Dipole Alignment $a_1 \times 10^{60}$ (erg cm^6 K)	Induction $a_2 \times 10^{60}$ (erg cm^6)	Dispersion $a_3 \times 10^{60}$ (erg cm^6)	Dispersion $a_4 \times 10^{76}$ (erg cm^8)	Dispersion $a_5 \times 10^{92}$ (erg cm^{10})	Reference
1	H_2	0	0	11.4	31	45	
2	N_2	0	0	57.2	120	130	
3	O_2	0	0	39.8	96	120	Margenau
4	H_2O	55700	10	47	114.9	127.9	
5	Dry Air	0	0	52.6	114.9	127.9	
6	H_2-N_2	0	0	25.6	61	76.5	Authors
7	Moist Air	0	5	50.2	114.9	127.9	

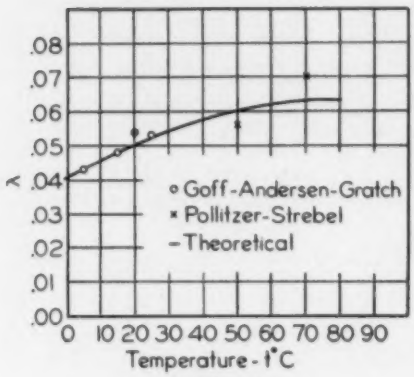


Fig. 3

Interaction Constants

In order to obtain appropriate coefficients in Equation (6) for mixtures of two gases it is necessary to employ certain combination rules suggested by the theory though, in principle, these can be computed directly from the quantum mechanical equations. Thus, the a_1 for a mixture should be the *geometric* mean of the a_1's of the individual gases, since this coefficient is proportional to the product $p_1^2 p_2^2$. An *arithmetic* mean can be used for the coefficient a_2 if the polarizabilities of the two gases do not differ too greatly. The problem is more difficult in the case of the dispersion coefficients, though for a_3 it is clear that the *geometric* mean is the best approximation. Regarding the higher coefficients a_4 and a_5 *geometric* averaging is recommended especially since the corresponding terms in Equation (6) contribute relatively little to the final result.

Row 6 gives the coefficients for H_2-N_2 mixtures as computed by means of the combination rules explained above. Again using the Verschoyle data the interesting comparison shown in Table 4 is obtained.

As mentioned previously the Verschoyle data are not very accurate. In fact, judging from the values given by Cragoe[9] and by Keyes[10] for 0 C, they may be in error by as much as 10 per cent. Nevertheless, the comparisons of Tables 3 and 4 attest to the powerfulness of present theory, especially when it is noticed that, in the case of H_2-N_2 mixtures, λ is so much larger and depends so much more markedly on temperature than in the case of moist air.

Before attempting to calculate the interaction constant for moist air, some explanation of how the coefficients in Table 2 (Row 4) for water vapor alone were obtained, is in order. The values of a_1, a_2, a_3 were taken from Margenau[11] who in turn quoted London[12]. The higher coefficients a_4, a_5 were not given. However, since the ratios $a_3:a_4:a_5$ do not vary greatly amongst the various gases and since the values of a_3 for water and for dry air (Row 5) are not radically different, it was assumed that the same values of a_4 and a_5 could be used for water as for dry air. Whether or not this assumption is exactly correct makes little difference inasmuch as the higher terms containing r^{-8} and r^{-10} contribute relatively little to the final result.

Regarding r_0 for water vapor, this would have to be allowed to vary markedly with temperature in order to obtain perfect agreement with observed data even in the range —10 to 80 C. The reason lies, of course, in the use of the dotted curve of Fig. 1 which is not an adequate approximation in the case of water with its strong permanent dipole moment. Ultimate refinement in the calculations with a view toward extrapolating experimental findings over the widest possible temperature range will be reserved for a later paper. Meantime a constant value $r_0 = 3.064 \times 10^{-8}$ cm adjusted to perfect agreement at 350 K will be used.

Following Fowler's[13] suggestion of averaging the r_0's *arithmetically* and using the combination rules explained above for determining the coefficients in Equation (6) for water-dry air mixtures (Row 7, Table 2), the interaction constant A_{aw} can be calculated as a function of temperature by means of Equation (5). Then from known values of A_{ww} and A_{aa}, the corresponding values of λ are computed. Fig. 3 shows the remarkable agreement thus obtained with the experimental values.

The calculated values of the interaction constant for moist air have been reduced to the following empirical equation,

$$A_{aw} = \frac{16{,}274}{T} \times 10^{42/T} - 42.51 \quad \text{(cc/mol)}$$

valid in the range —10 to 80 C, it being understood that T is in degrees Kelvin. Comparison with experimental values is repeated in Table 5.

Table 5—Interaction Constant λ for Moist Air

T(C)	Observed	Calculated
5	0.043	0.043
15	0.048	0.048
20	0.054	0.050
25	0.053	0.052

Summary

Final values of the interaction constant for moist air for the range 5 to 25 C are reported. The experimental measurements from which these are derived have been critically evaluated to ascertain the limits of uncertainty in the final results. These limits of uncertainty were found to be sufficiently narrow to insure that subsequent calculations of the various thermodynamic properties of moist air based on the final values of λ will not be in error more than about ±0.03 per cent.

Considerable confidence in the permanence of the experimental values is afforded by the remarkable agreement with values calculated from recent quantum statistical theory. Further refinements in the calculations promise to provide a reliable basis for extrapolation to cover at least the range —100 to 200 F. It can be concluded from the theory and inferred from the fact that the high-pressure measurements of Pollitzer & Strebel conform to the theory that the various thermodynamic properties of moist air can be calculated from present knowledge of the interaction constant for pressures possibly as high as 100 atmospheres.

Acknowledgment

The authors wish to express appreciation of the generous support given by the American Society of Heating and Ventilating Engineers in the prosecution of this cooperative investigation. They wish also to say that during the latter half of the investigation they found repeated occasions to admire the expertness of Dr. A. C. Bates, Assistant Professor of Mechanical Engineering, Lehigh University, in designing and building the apparatus with which the measurements here reported were made.

[9] Loc. Cit. See Note 5.
[10] Loc. Cit. See Note 6.
[11] Loc. Cit. See Note 3.
[12] F. London, Transactions Faraday Society 33², 8, 1937.
[13] Statistical Mechanics, by R. H. Fowler. (Cambridge University Press, 1936, p. 308.)

Table 3—Second Virial Coefficients A (T) (cc/mol)

Gas	0 C Observed	0 C Calculated	20 C Observed	20 C Calculated	$r_0 \times 10^8$ cm
H_2	—14.2	—13.9	—14.9	—15.4	2.975
N_2	+11.1	+11.1	+ 6.1	+ 6.16	3.457

Table 4—Interaction Constant for H_2-N_2 Mixtures

	0 C Observed	0 C Calculated	20 C Observed	20 C Calculated
$A_{H_2-N_2}$ (cc/mol)	—12	—8	—14	—11
λ	7.7	5.7	3.2	2.4

SEMI-ANNUAL MEETING PROGRAM

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

William Penn Hotel—June 6-8, 1943—Pittsburgh, Pa.

Sunday, June 6

10:00 a. m. Research Executive Committee Meeting
1:00 p. m. REGISTRATION—(Silver Room)
1:30 p. m. Council Meeting—(Forum Room)
2:00 p. m. Committee on Heat Transfer in Finned Tubes—(Parlor B)
4:00 p. m. Ladies Tour of Inspection
6:00 p. m. Reception of Visiting Members and Ladies—(Cardinal Room)
7:30 p. m. Committee on Research—(Parlors E and F)

Monday, June 7

9:00 a. m. REGISTRATION—(Silver Room)
9:30 a. m. TECHNICAL SESSION—(Urban Room)
9:35 a. m. Welcome to Pittsburgh—Frank L. Duggan, President, Pittsburgh Chamber of Commerce
9:45 a. m. Reports of Officers and Committees
10:10 a. m. Amendments to By-Laws
10:20 a. m. Performance of a Residential Panel Heating System, by H. F. Randolph and J. B. Wallace
10:40 a. m. Discussion
12:05 p. m. Adjournment
12:15 p. m. Welcome Luncheon—*Toastmaster*, G. G. Waters, President, Pittsburgh Chapter; *Speaker*, Howard Coonley, Director, Conservation Div., War Production Board; *Subject*, Fuel Conservation
2:00 p. m. TECHNICAL SESSION—(Urban Room)
2:10 p. m. Final Values of the Interaction Constant for Moist Air, by John A. Goff, J. R. Andersen and S. Gratch
2:30 p. m. Discussion
3:00 p. m. Study of Actual vs. Predicted Cooling Load on an Air Conditioning System, by J. N. Livermore
3:20 p. m. Discussion
4:00 p. m. Spray Nozzle Performance in a Cooling Tower, by L. M. K. Boelter and S. Hori
4:20 p. m. Discussion
4:45 p. m. Adjournment
3:00 p. m. Ladies Tea—(Suite 468-70)
5:00 p. m. War Service Committee—(Parlor D)
5:00 p. m. Chapter Delegates Conference—(Parlors E and F)
7:30 p. m. Committee on Heavy Duty Air Heating Furnaces
8:00 p. m. Committee on Psychrometry—(Parlor D)
8:00 p. m. Guide Publication Committee Meeting—(Parlor B)
8:00 p. m. Nominating Committee Meeting—(Adonis Room)
9:00 p. m. Informal Get-together—A Night at the Nixon

Tuesday, June 8

9:00 a. m. TECHNICAL SESSION—(Urban Room)
9:05 a. m. Use of the Down-Draft Coking Method for Smokeless Combustion, by J. R. Fellows and J. C. Miles
9:25 a. m. Discussion
10:00 a. m. Field Study of Comfort Reactions of Apartment Dwellers Under Fuel Oil Rationing, by Sallye Hamilton
10:15 a. m. Discussion
10:40 a. m. Heat Transmission Through Insulation as Affected by Orientation of Wall, by F. B. Rowley and C. E. Lund
11:00 a. m. Discussion
11:30 a. m. Graphical Method of Calculating Heat Losses, by P. D. Close
11:45 a. m. Discussion
12:15 p. m. Adjournment
11:00 a. m. Ladies Brunch-Bridge—(Adonis Room)
1:30 p. m. Meeting of Technical Advisory Committee on Radiation and Comfort—(Parlor G)
2:00 p. m. TECHNICAL SESSION—(Urban Room)
2:05 p. m. The Economic Factors in Converting Recirculated Air for Ventilation, by H. E. Ziel and Henry Sleik
2:25 p. m. Discussion
3:00 p. m. Panel Discussion—John Howatt, *Chairman; Subject*—Will Current Ventilating System Operation Undermine Public Health and Efficiency. Dr. C.-E. A. Winslow, New Haven; John Paul Jones, Cleveland; L. L. Lewis, Syracuse
4:45 p. m. Adjournment
7:00 p. m. Dinner—(Urban Room)
Toastmaster, F. C. McIntosh; *Speaker*, Dr. Allen A. Stockdale; *Subject*—Democracy Can Do It
Presentations: Past President's Emblem and Memory Book to Prof. E. O. Eastwood

Howard Coonley

Dr. A. A. Stockdale

J. N. Livermore

H. F. Randolph

H. E. Ziel

C. M. Humphreys
Vice-Chairman

M. F. Blankin
President

R. B. Stanger
General Chairman

P I T T S B U R G H

The Semi-Annual Meeting of the Society opens at Pittsburgh, June 7, with a two-day program of technical discussions. Pittsburgh Chapter members will be the hosts, and they have planned an informal reception for visiting members and ladies on Sunday evening, June 6.

A number of important speakers will address the meeting, and at the Welcome Luncheon on Monday, June 7, Howard Coonley, Director, Conservation Div., War Production Board, Washington, D. C., will talk on the subject of Fuel Conservation. Mr. Coonley is a past president of the *National Association of Manufacturers*, and was president and is still a director of the *American Standards Association*. He was formerly president of Boston Chamber of Commerce, and is a member of the *ASME*, and the *Association of Arts and Sciences*. Since 1913 he has served as president with the Walworth Co., Boston, manufacturers of valves, pipe fittings and pipe tools.

At the Semi-Annual dinner June 8 Dr. Allen A. Stockdale, New York, will speak and his subject is, "Democracy Can Do It." Dr. Stockdale is ranked as one of America's finest speakers on industrial subjects. After his graduation from Boston University School of Theology he did post graduate work at several universities and has held pastorates at Boston, Chicago, Toledo, and Washington, D. C. He is the author of many well-known bits of poetry and has been an editorial contributor to a number of national magazines.

The program contains much of interest for Society members who attend this wartime conference.

Committee on Arrangements

General Chairman, Ralph B. Stanger; *Vice-Chairman*, Clark M. Humphreys.

Hospitality Committee: F. C. McIntosh, *Chairman*, T. M. Dugan, John L. McCullough, Robert A. Miller, H. Lee Moore, Arthur F. Nass, Bertram B. Reilly, G. L. Simpson.

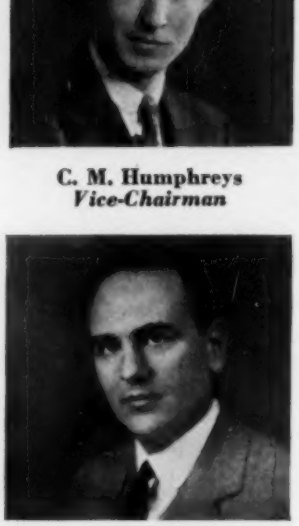
Entertainment Committee: Harold E. Park, *Chairman*, H. A. Beighel, Van A. Reed, Jr., Chas. H. Schneider, R. H. Sweeney.

Dinner Committee: Edward C. Smyers, *Chairman*, Glen Moore Comstock, Horton J. Kirkendall, Albert W. Marshall, Paul C. Strauch.

Ladies' Committee: Mrs. Theo. F. Rockwell, *Chairman*, Mrs. John F. Collins, Jr., Mrs. Clark M. Humphreys, Mrs. David W. Loucks, Mrs. L. S. Maehling, Mrs. F. C. McIntosh, Mrs. Robert A. Miller, Mrs. H. Lee Moore, Mrs. Arthur F. Nass, Mrs. Bertram B. Reilly, Mrs. Edward C. Smyers, Mrs. Paul C. Strauch, Mrs. G. G. Waters.

Publicity Committee: David W. Loucks, *Chairman*, John F. Collins, Jr., Paul A. Edwards, Albert F. Metzger.

Finance Committee: L. S. Maehling, Edward H. Reismeyer, Jr., Theo. F. Rockwell.



F. C. McIntosh
Hospitality

E. C. Smyers
Dinner

Mrs. T. F. Rockwell
Ladies

J. F. Collins, Jr.
Chapter Relations

John Howatt
Panel Discussion

C. M. Ashley
Committee on Research

SUMMARY OF LOCAL CHAPTER MEETINGS

CHAPTER	MEETING DATE	SUBJECT	SPEAKERS	OTHER FEATURES	ATTENDANCE	ATTENDANCE RATIO*
Illinois	May 10	The Society's Activities in War Time.	Pres. M. F. Blankin, Philadelphia, Pa.	Annual Illinois Chapter Meeting and Ladies Night. Installation of Officers.	104	0.75
Northern Ohio	May 10	High Lights Upon Fan Selection from the Acoustic Viewpoint.	T. A. Walters.	Election of Officers as follows: Pres. P. D. Gayman; Vice-Pres. W. A. Evans; Sec'y, G. B. Priester; Treas. R. L. Clark. Board of Governors: C. M. H. Kaercher, R. H. Cutting, J. F. Platz.	40	0.60
North Carolina	May 7	Flow of Air and Gases in Various Systems.	Vice-Pres. S. H. Downs, Kalamazoo, Mich.	Election of Officers as follows: Pres. F. J. Reed; Vice-Pres. K. W. Selden, Jr.; Sec'y.-Treas. C. Z. Adams. Board of Governors: Officers and E. R. Harding, E. S. Theiss and P. L. Guest, Jr.	21	0.53
St. Louis	May 4	Annual Meeting—Election of Ofcers as follows: Pres. C. F. Boester; 1st Vice-Pres. G. B. Rodenheiser; 2nd Vice-Pres. W. J. Oonk; Sec'y. B. C. Simons; Treas. H. W. Mc Larney. Board of Governors: Officers and J. S. Malone, E. H. Ronsick, J. S. Rosebrough and L. R. Szombathy.	None.	Movies — Manufacture and Testing of Medium Tank. Manufacture of B-26 Army Bomber. U. S. News Review (Issue No. 4).	20	0.37
Ontario	May 3	Story of Oil.	Mr. Mitchell.	Ontario Chapter's Awards to University of Toronto Student writing best thesis on heating, piping and air conditioning. Annual reports of Committees. Officers elected as follows: Pres. W. C. Kelly; Vice-Pres. A. S. Morgan; Sec'y-Treas. H. R. Roth; Board of Governors: H. G. Hill, J. P. Fitzsimons, V. J. Jenkinson.	56	0.53
Manitoba	April 28	Business Meeting. Report of Nominating Committee. Review of paper on Conversion from Oil to Coal.	F. T. Ball, Winnipeg.		14	0.58

Chapter	Meeting Date	Subject	Speakers	Other Features	Attendance	Attendance Ratio*
Western New York	April 26	The Philosophy of the Japanese People.	Dr. Claire Pettit, Supt. of Schools, Lockport, N. Y.	Election of Officers as follows: Pres. S. M. Quackenbush; 1st Vice-Pres. S. W. Strouse; 2nd Vice-Pres. F. A. Moesel; Treas. B. C. Candee; Sec'y. Herman Seelbach, Jr.; Board of Governors: M. C. Beman, Joseph Davis, Roswell Farnham, D. J. Mahoney and H. C. Schafer.	32	0.58
Massachusetts	April 20	Reversed Cycle Heating.	A. J. Lawless.		35	0.60
Montreal	April 19	Air Filters (illustrated with slides).	C. A. Booth, Fiberglas Canada, Ltd. W. G. Hole, Darling Bros., Ltd.		40	0.65
New York	April 19	Electrostatic Precipitation.	J. H. Squires, Jr.	Meeting held jointly with the N. Y. chapter of Producer's Council, Inc.	67	0.40
Wisconsin	April 19	Electrostatic Air Cleaning in Industrial Plants.	H. H. Van Epps.		62	0.88
Kansas City	April 15	The Society's Activities in War Time.	Pres. M. F. Blankin, Philadelphia.	E. K. Campbell spoke on membership, also on fuel rationing.	56	1.02
Nebraska	April 14	The Development and Performance of Direct-Fired Unit Heaters.	R. M. Rush, Pittsburgh, Pa.	Dinner.	12	0.67
Southern California	April 14	Food Dehydration. A Revived Industry.	Dr. E. A. Beavens, Food Technologist, U. S. Dept. of Agriculture.	Announcement that May meeting would be on 17th, to welcome Pres. M. F. Blankin, Philadelphia, Pa.	47	0.39
Washington, D. C.	April 14	Methods for Testing and Properties of Temperature Insulations.	Lieut. E. R. Queer, U.S.N.R.	Dinner.	21	0.21
Michigan	April 12	The Manpower Problem in Engineering.	Dr. B. M. Woods, University of California, Berkeley, Calif.	Movies — Michigan Angler—Michigan Trout Fishing.	43	0.58
North Texas	April 12	The Society's Activities in War Time.	Pres. M. F. Blankin, Philadelphia, Pa.	Reports for Committees.	41	0.60
Pittsburgh	April 12	Air Conditioning of Blast Furnaces.	H. M. Graham, Pittsburgh, Pa.	Discussion.	44	0.67
Philadelphia	April 8	Food Dehydration.	J. C. Patterson, Syracuse, N. Y.	Samples of foods showing relative spaces occupied before and after dehydration were shown; also samples of pressed packed dehyrated foods.	120	1.00

*The attendance ratios shown represent the meeting attendance divided by the Chapter membership. These will be useful as a partial indication of interest shown by local chapter members in various types of subjects programmed by other local chapters, and may be helpful in deciding on subjects for other chapter meetings.

Candidates for Membership

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 30 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by June 15, 1943, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
BRINDELL, CARL E., Cressy-Legget-Brindell, New Orleans, La.	L. V. Cressy J. J. Joyce	G. E. May J. S. Burke
CHRISTIE, JOHN A., Mfrs. Agt., Waterous, Ltd., Brantford, Can.	H. H. Angus S. A. Jennings	M. S. Woollard W. R. Blackhall
CRESSY, L. RENE, Cressy-Legget-Brindell, New Orleans, La.	L. V. Cressy J. J. Joyce	G. E. May J. S. Burke
CRUMP, SAMUEL, Pres. & Mgr., Samuel Crump Co., Ltd., Toronto, Ont., Can.	V. J. Jenkinson S. A. Jennings	J. A. Clifton R. S. Mathison
DAHLSTROM, GODFREY A., Mech. Engr., Smith, Hinchman & Grylls, Detroit, Mich. *(Advancement)*	W. McNamara F. C. Winterer	A. B. Algren R. C. Jordan
DEGILIO, LOUIS, Refrig. Dept., Robert Elder Carriage Works, Toronto, Ont., Can.	V. J. Jenkinson *J. B. Maydon	*W. E. Weaver H. R. Roth
EARHART, JOE S., Mfg. & Sales Engr., Los Angeles, Calif. *(Reinstatement)*	R. L. Gifford O. W. Ott	J. F. Park W. S. Kilpatrick
GLASS, ROBERT, Secy.-Treas. & Supt., Partridge-Halliday, Ltd., Winnipeg, Man., Can.	F. T. Ball R. L. Kent	Ivan McDonald E. Anderson
GROSSMAN, RALPH, Combustion Sales Engr., Volcano, Ltd., Montreal, Que., Can.	A. B. Madden S. W. Salter	A. M. Peart R. R. Noyes
HELFINSTINE, ROY J., Assoc. Mech. Engr., Illinois State Geological Survey, Urbana, Ill.	S. Konzo A. P. Kratz	R. A. Norman M. P. Cleghorn
HEMINGWAY, JOHN C., JR., Distributor, H. C. Little Burner Co., Inc., San Rafael, Calif.	C. M. Mast G. M. Simonson	P. R. Babcock J. F. Kooistra
KAVENY, J. GORDON, Pres. & Sales Mgr., Kaveny Bros. Co., Montclair, N. J.	L. B. Ray B. H. Schulze	C. R. Morris H. L. Hosking
KEETON, ROBERT W., M.D., Head, Dept. of Medicine, University of Illinois, College of Medicine, Chicago, Ill.	F. E. Giesecke A. C. Willard	John Howatt E. P. Heckel
KREMER, RICHARD H., Secy., Kupferle-Hicks Htg. Co., St. Louis, Mo.	J. W. Cooper George Myers	E. E. Carlson *W. D. Thompson
LINDSLEY, FORREST A., Sales, Crane Co., Detroit, Mich.	C. A. Strand W. G. Boales	G. D. Winans F. X. Marzolf
MARC, HENRI M., Asst. Dir. of Research, The Philip Carey Mfg. Co., Cincinnati, Ohio.	R. H. Heilman R. E. Kramig, Jr.	G. V. Sutfin R. W. Sigmund
MCLEOD, CLARENCE H., Application Engr., York Ice Machinery Corp., Dallas, Tex.	W. H. Moler J. A. Ray	E. T. Gessell L. C. McClanahan
MCMICHAEL, CHESTER L., Sales Engr., H. H. Wright Co., Kansas City, Mo.	M. M. Rivard R. B. Mason	W. A. Russell F. C. Burns
MOORE, ROBERT E., Archt., Moody and Moore, Winnipeg, Man., Can.	G. C. Davies P. L. Charles	W. Worton W. Glass
MUSSER, NEIL B., SR., Naval Archt., U. S. Maritime Commission, Oakland, Calif.	S. W. Terry M. I. Blumenthal	J. F. Kooistra N. H. Peterson
NOVOLANSKY, SYDNEY I., Flight Sgt., Royal Canadian Air Force, Winnipeg, Man., Can.	W. Worton G. C. Davis	I. McDonald E. Anderson
OTTUM, ALVIN L., Htg. & Vtg. Engr., Glenn L. Martin-Nebraska Co., Omaha, Neb.	G. E. Merwin E. F. Adams	W. R. White R. B. Saxon
PETERSON, B. G., Mfrs. Repr., Omaha, Neb. *(Advancement)*	John Mathis D. D. Williams	H. W. Stanton E. F. Adams
ROSER, EDWARD, III, Air Cond. & Refrig. Dept., U. S. Engrs., Fort Leavenworth, Kan.	H. D. Betz *C. F. Kramer	*C. R. Moore *E. T. Gaskill
SAUNDERS, DOUGLAS G., Estimator & Supt., John Plaxton Co., Ltd., Winnipeg, Man., Can.	P. L. Charles D. F. Michie	J. R. Stephenson E. Anderson
SCHROEDER, DELMAN E., Test Engr., Murray Iron Works Co., Burlington, Iowa.	C. A. Wheeler *L. T. Brown	R. A. Norman B. E. Landes
SIGGINS, GEORGE S., Mfrs. Agent, East Orange, N. J.	*H. R. Carr *W. L. Sanborn	*H. K. Eilers *W. P. Gilbert

SINGLETON, ARTHUR B., Chief Engr., Kerr Machinery Co., Detroit, Mich.

WALSH, JAMES A., Pres., Air Conditioning Co., Houston, Tex. *(Advancement)*

WILLIAMS, E. BRYAN, Laboratory Mgr., The Torrington Mfg. Co., Torrington, Conn.

H. D. Chappell
W. H. Old
M. F. Blankin
H. U. Bible
W. L. Upson
*R. S. Storrs

J. T. Reader
E. D. Sheley
A. M. Chase, Jr.
R. F. Taylor
*H. P. Staats
*H. M. Risedorf

*Non-member.

Candidates Elected

In the past issues of the Journal of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Committee on Admission and Advancement and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. B-III, Sec. 8, of the By-Laws, the following list of candidates elected:

MEMBERS

BERLET, E. JOHN, JR., Application Engr., York Ice Machinery Corp., Philadelphia, Pa.

BLAKE, ALBERT H., Gen. Mgr., B. F. Sturtevant Co. of Canada, Ltd., Toronto, Ont., Can. *(Reinstatement)*

BROWN, GUY M., Mech. and Elec. Engr., Minneapolis, Minn.

CASKEY, T. C., Dist. Engr., B. F. Sturtevant Co., Seattle, Wash.

CONGER, HENRY L., Assoc. Engr., U. S. Engr. Dept., Fortifications Subdivision, Punahou, Honolulu, T. H.

FALK, DAVID S., Engr., U. S. Public Health Service, Bethesda, Md. *(Advancement)*

FLINN, JAMES D., Engr., J. J. Nolan & Co., Memphis, Tenn.

GRIFFIN, DEWITT CHARLES, Cons. Mech. Engr., Griffin & Lowe, Seattle, Wash. *(Reinstatement)*

HEAVEN, LEWIS P., Owner, Heaven Engrg. Co., Kansas City, Mo.

HOULIHAN, EDMUND T., Asst. Sales Mgr., Taco Heaters, Inc., New York, N. Y.

HUNKEN, WALTER L., Regional Mgr., B. F. Sturtevant Co., Greensboro, N. C.

KUCERA, HENRY T., Vice-Pres., Marsh Tritrol Co., Chicago, Ill.

LILJA, OSCAR L., Htg. & Vtg. Engr., Northwest Airlines, Inc., St. Paul, Minn. *(Advancement)*

LEWIS, JOHN G., Pres., John G. Lewis Plbg. & Htg. Co., Inc., Kansas City, Mo. *(Reinstatement)*

LORIMER, CARL F., Br. Mgr., Kewanee Boiler Corp., Kewanee, Ill.

MACKEY, C. OSBORN, Prof. Heat Power Engrg., Cornell University, Ithaca, N. Y.

MASON, GAIL C., Pres., Warm Air Htg. Supply Co., Detroit, Mich. *(Reinstatement)*

MAUTNER, ERWIN W., Partner, Mid-West Heat Service, Chicago, Ill.

MCCONACHIE, L. L., Owner, L. L. McConachie Co., Detroit, Mich. *(Advancement)*

O'BRIEN, T. J., Partner, Allied Archts. & Engrs., Memphis, Tenn.

PAINTER, D. HOWARD, Mfrs. Agt., Kansas City, Mo. *(Reinstatement)*

PARSONS, FELIX N., Assoc. Mech. Engr., U. S. Nitrate Plant No. 2, Wilson Dam, Ala.

PETERKIN, S. M., Pres. & Engr., Michael Stuart Co., Ltd., Toronto, Ont., Can. *(Reinstatement)*

RUDOLPH, ROBERT R., Naval Archt., Associated Shipbuilders, Harbor Island, Seattle, Wash.

RUNNINGS, HENRY MARK, Mech. Engrg., Detroit Board of Education, Detroit, Mich.

SCHMIDT, A. F., Designer, Air Cond., Agfa Ansco, Div. of General Aniline & Film Corp., Binghamton, N. Y.

WILHELM, JOSEPH E., Chief Engr., Avery Engrg. Co., Cleveland, Ohio *(Advancement)*.

WILLIAM, FREDERIC C., Sales Engr., American Blower Corp., Boston, Mass.

ASSOCIATES

ASHCRAFT, J. PHILLIP, Br. Mgr., Minneapolis-Honeywell Reg. Co., Dallas, Tex.

BECKER, GEORGE E., Service Mgr., Frigid Refrigerator Service Corp., St. Louis, Mo.

BORNQUIST, GEORGE W., Pres., Bornquist, Inc., Chicago, Ill.

CATLETT, W. A., Owner, Catlett Engrs., Dallas, Tex.

FENNER, N. P., Hoffman Specialty Co., Chicago, Ill. *(Reinstatement)*

GROSSMAN, HARRY E., Sales Engr., Haynes Selling Co., Inc., Philadelphia, Pa. *(Reinstatement)*

KIRSCHHOFER, FERD J., Owner, Federal Home Htg. Co., Buffalo, N. Y.

LITTLE, RAYMOND, Com. Mgr. & Utilization Engr., Equitable Gas Co., Pittsburgh, Pa.

PEGG, EDWARD H. R., Mech. Engr., Westinghouse Elec. & Mfg. Co., Cleveland, Ohio.

SMITH, LAWRENCE J., Dir. of Research, Bell & Gossett Co., Morton Grove, Ill.

WAGNER, WILBUR J. O., Owner, Wagner Temperature Store, Jefferson City, Mo.

JUNIORS

BALLAGH, A. BRUCE, Sales Engr., B. F. Sturtevant Co. of Canada, Ltd., Toronto, Ont., Can.

BARLOW, E. JOHN, Htg., Vtg. & Gen. Service Engr., A. O. Smith Corp., Milwaukee, Wis.

DAVIS, MAURICE M., Asst. Plant Engr., Conmar Products, New York, N. Y.

MOSS, ALFRED W., Dept. Mgr., Walter Woods, Ltd., Winnipeg, Man., Can.

NOTTAGE, HERBERT B., Asst. Project Engr., Pratt & Whitney Aircraft, East Hartford, Conn.

SCHNEEBERG, FLOYD H., Cpl., U. S. Army, Fort Francis E. Warren, Wyoming.

WHITE, JOHN HAZEN, Pres. & Treas., Taco Heaters, Inc., New York, N. Y.

WRIGHT, L. T., JR., Asst. Prof. Heat Power Engrg., Cornell University, Ithaca, N. Y.

STUDENTS

BOWLER, ROBERT W., Student, Carnegie Institute of Technology, Pittsburgh, Pa.

CHIPMAN, EDWARD E., JR., Student, Carnegie Institute of Technology, Pittsburgh, Pa.

DINHAM, ROBERT ELTON, Student, University of Minnesota, Minneapolis, Minn.

MINOR, JAMES E., Student, Carnegie Institute of Technology, Pittsburgh, Pa.

SHER, ALVIN I., Student, Carnegie Institute of Technology, Pittsburgh, Pa.

Officers

President.....M. F. Blankin
First Vice-President.....S. H. Downs
Second Vice-President.....C.-E. A. Winslow
Treasurer.....E. K. Campbell
Secretary.....A. V. Hutchinson
Technical Secretary.....Carl H. Flink

Council

M. F. Blankin, *Chairman* S. H. Downs, *Vice-Chairman*

Three Years: J. F. Collins, Jr., James Holt, E. N. McDonnell, T. H. Urdahl.

Two Years: L. G. Miller, A. J. Offner, A. E. Stacey, Jr., B. M. Woods.

One Year: E. O. Eastwood, A. P. Kratz, W. A. Russell, L. P. Saunders, C. Tasker.

Council Committees

Executive—E. O. Eastwood, *Chairman*, A. P. Kratz, E. N. McDonnell.

Finance—J. F. Collins, Jr., *Chairman;* C.-E. A. Winslow, B. M. Woods.

Membership—E. K. Campbell, *Chairman*, A. J. Offner, W. A. Russell.

Meetings—S. H. Downs, *Chairman*, James Holt, C. Tasker.

Standards—L. P. Saunders, *Chairman*, L. G. Miller, T. H. Urdahl.

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Advisory Council

E. O. Eastwood, *Chairman;* Homer Addams, D. S. Boyden, W. H. Carrier, S. E. Dibble, W. H. Driscoll, W. L. Fleisher, H. P. Gant, F. E. Giesecke, E. Holt Gurney, L. A. Harding, H. M. Hart, C. V. Haynes, E. Vernon Hill, John Howatt, W. T. Jones, D. D. Kimball, G. L. Larson, S. R. Lewis, Thornton Lewis, J. F. McIntire, F. B. Rowley and A. C. Willard.

Special Committees

Admission and Advancement: E. P. Heckel, *Chairman* (*one year*); T. T. Tucker (*two years*); H. Berkley Hedges (*three years*).

ASHVE-*ASTM-ASRE-NRC Committee on Thermal Conductivity*—F. C. Houghten, *Chairman;* C. B. Bradley, H. C. Dickinson, R. H. Heilman, E. R. Queer, F. B. Rowley, T. S. Taylor, G. B. Wilkes.

ASHVE-*IES Joint Committee on Lighting and Air Conditioning*—H. M. Sharp, *Chairman;* W. R. Beach, B. C. Candee, W. G. Darley, C. L. Kriba, Jr., P. M. Rutherford, Jr.

Chapter Relations—J. F. Collins, Jr., *Chairman;* L. P. Saunders, H. E. Sproull.

Constitution and By-Laws—L. T. Avery, *Chairman;* M. W. Bishop, R. A. Miller.

F. Paul Anderson Award—S. H. Downs, *Chairman;* Tom Brown, F. E. Giesecke, L. L. Lewis and F. B. Rowley.

Guide Publication—P. D. Close, *Chairman;* Thomas Chester, John James, S. Konzo, C. S. Leopold.

Publication: C. H. B. Hotchkiss, *Chairman* (*one year*); J. H. Walker (*two years*); L. E. Seeley (*three years*).

War Service: John Howatt, *Chairman;* W. H. Driscoll, E. N. McDonnell, L. E. Seeley, B. M. Woods.

Nominating Committee

Chapter	*Representative*	*Alternate*
Atlanta	T. T. Tucker	L. F. Kent
Cincinnati	M. E. Mathewson	E. W. McNamee
Connecticut	L. E. Seeley	H. E. Adams
Delta	G. E. May	G. C. Kerr
Golden Gate	B. M. Woods	
Illinois	E. M. Mittendorff	A. O. May
Iowa	F. E. Triggs	C. W. Helstrom
Kansas City	L. T. Mart	M. M. Rivard
Manitoba	Ivan McDonald	Einar Anderson
Massachusetts	E. G. Carrier	A. C. Bartlett
Michigan	M. B. Shea	S. S. Sanford
Minnesota	R. E. Backstrom	William McNamara
Montreal	G. P. Ste-Marie	R. R. Noyes
New York	H. H. Bond	C. S. Koehler
Nebraska	B. G. Peterson	W. R. White
North Carolina	F. E. P. Klages	Arvin Page
North Texas	T. H. Anspacher	
Oklahoma	E. T. P. Ellingson	E. F. Dawson
Ontario	V. J. Jenkinson	H. R. Roth
Oregon	B. W. Farnes	
Pacific Northwest	R. D. Morse	E. H. Langdon
Philadelphia	H. H. Mather	Edwin Elliot
Pittsburgh	E. C. Smyers	E. H. Riesmeyer, Jr.
St. Louis	C. F. Boester	M. F. Carlock
South Texas	J. A. Walsh	A. J. Rummel
Southern California	W. O. Stewart	Leo Hungerford
Washington, D. C.	J. W. Markert	F. A. Leser
Western Michigan	T. D. Stafford	L. G. Miller
Western New York	H. C. Schafer	S. M. Quackenbush
Wisconsin	C. H. Randolph	Ernest Szekely

Officers of Local Chapters

ATLANTA: *Organized*, 1937. *Headquarters*, Atlanta, Ga. *Meets*, First Monday. *President*, A. H. Koch, 3687 Peachtree Rd. *Secretary*, L. F. Lawrence, Jr., 304-101 Marietta St. ***CINCINNATI:*** *Organized*, 1932. *Headquarters*, Cincinnati, O. *Meets*, Second Tuesday. *Honorary President*, Capt. C. E. Hust. *President*, Albert Buenger, Hotel Gibson. *Secretary*, E. J. Richard, 2137 Reading Rd. ***CONNECTICUT:*** *Organized*, 1940. *Headquarters*, New Haven, Conn. *President*, C. J. Lyons, Wilson Ave., S. Norwalk. *Secretary*, J. R. Smak, 160 Morehouse Highway, Fairfield. ***DELTA:*** *Organized*, 1939. *Headquarters*, New Orleans, La. *Meets*, Second Tuesday. *President*, G. C. Kerr, 1401 Tchoupitoulas St. *Secretary*, L. V. Cressy, 916 Union St. ***GOLDEN GATE:*** *Organized*, 1937. *Headquarters*, San Francisco, Calif. *Meets*, First Wednesday. *President*, R. A. Folsom, 150 Hooper St. *Secretary*, R. B. Holland, 1275 Folsom St. ***ILLINOIS:*** *Organized*, 1906. *Headquarters*, Chicago, Ill. *Meets*, Second Monday. *President*, Chas. E. Price, Room 1605, 6 N. Michigan Ave. *Secretary*, C. M. Burnam, Jr., Room 1605, 6 N. Michigan Ave.

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IOWA: *Organized*, 1940. *Headquarters*, Des Moines, Ia. *Meets*, Second Tuesday. *President*, C. W. Helstrom, 1614 Thompson. *Secretary*, B. E. Landes, 511 Hubbell Bldg. ***KANSAS CITY:*** *Organized*, 1917. *Headquarters*, Kansas City, Mo. *Meets*, Second Monday. *President*, M. M. Rivard, 4550 Main St. *Secretary*, D. M. Allen, 310 Board of Trade Bldg. ***MANITOBA:*** *Organized*, 1935. *Headquarters*, Winnipeg, Man. *Meets*, Third Thursday. *President* Ivan McDonald, 44 Princess St. *Secretary*, Einar Anderson, 152 Bannerman Ave. ***MASSACHUSETTS:*** *Organized* 1912. *Headquarters*, Boston, Mass. *Meets*, Third Tuesday. *President*, E. G. Carrier, 704 Statler Bldg. *Secretary*, R. T. Kern, 51 Claflin St., Leominster. ***MICHIGAN:*** *Organized*, 1916. *Headquarters*, Detroit, Mich. *Meets*, First Monday after 10th of Month. *President*, M. B. Shea, 8019 Jos Campau. *Secretary*, W. H. Old, 1761 Forest Ave., W. ***MINNESOTA:*** *Organized*, 1918. *Headquarters*, Minneapolis, Minn. *Meets*, First Monday. *President*, William McNamara, 850 Cromwell Ave., St. Paul. *Secretary*, A. W. Schultz, 240 Seventh Ave., S., Minneapolis.

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MONTREAL: *Organized*, 1936. *Headquarters*, Montreal, Que. *Meets*, Third Monday. *President:* F. A. Hamlet, 1010 St. Catherine St., W. *Secretary*, R. R. Noyes, 630 Dorchester St., W. ***NEBRASKA:*** *Organized*, 1940. *Headquarters*, Omaha. *Meets*, Second Tuesday. *President*, G. E. Merwin, 5012 Parker St. *Secretary*, E. F. Adams, 1227 So. 52nd St. ***NEW YORK:*** *Organized*, 1911. *Headquarters*, New York, N. Y. *Meets*, Third Monday. *President*, H. H. Bond, 10 E. 40th St. *Secretary*, P. G. Griess, 189 Walnut Ave., Bogota, N. J. ***NORTH CAROLINA:*** *Organized*, 1939. *Headquarters*, Durham, N. C. *Meets*, Quarterly. *President*, F. J. Reed, 263 College Station. *Secretary*, C. Z. Adams, 312 Piedmont Bldg., Greensboro. ***NORTH TEXAS:*** *Organized*, 1938. *Headquarters*, Dallas, Tex. *Meets*, Second Monday. *President*, M. L. Brown, 3500 Commerce St. *Secretary*, E. T. Gessell, Thomas Bldg. ***NORTHERN OHIO:*** *Organized*, 1916. *Headquarters*, Cleveland, O. *Meets*, Second Monday. *President*, P. D. Gayman, 2142 E. 19th St. *Secretary*, G. B. Priester, Case School of Applied Science.

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OKLAHOMA: *Organized*, 1935. *Headquarters*, Oklahoma City, Okla. *Meets*, Second Monday. *President*, E. F. Dawson, University of Oklahoma, Norman. *Secretary*, E. T. P. Ellingson, 314 Savings Bldg., Oklahoma City. ***ONTARIO:*** *Organized*, 1922. *Headquarters*, Toronto, Ont. *Meets*, First Monday. *President*, W. C. Kelly, 602 King St., W. *Secretary*, H. R. Roth, 57 Bloor St., W. ***OREGON:*** *Organized*, 1939. *Headquarters*, Portland, Ore. *Meets*, Thursday after First Tuesday. *President*, J. A. Freeman, 1623 S. E. 11th Ave. *Secretary*, G. H. Risley, 801 S. W. Stark St. ***PACIFIC NORTHWEST:*** *Organized*, 1928. *Headquarters*, Seattle, Wash. *Meets*, Second Tuesday. *President*, H. T. Griffith, 1411 Fourth Avenue Bldg. *Secretary*, R. E. LeRiche, 6345 39th, S. W., Seattle. ***PHILADELPHIA:*** *Organized*, 1916. *Headquarters*, Philadelphia, Pa. *Meets*, Second Thursday. *President*, H. H. Mather, 611 S. Front St. *Secretary*, M. G. Kershaw, du Pont Bldg., Wilmington, Del. ***PITTSBURGH:*** *Organized*, 1919. *Headquarters*, Pittsburgh, Pa. *Meets*, Second Monday. *President*, G. G. Waters, 1841 Oliver Bldg. *Secretary*, E. H. Riesmeyer, Jr., 231-33 Water St.

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ST. LOUIS: *Organized*, 1918. *Headquarters*, St. Louis, Mo. *Meets*, First Tuesday. *President*, C. F. Boester, 101 E. Essex, Kirkwood. *Secretary*, B. C. Simons, 3033 Locust Blvd. ***SOUTH TEXAS:*** *Organized*, 1938. *Headquarters*, Houston Texas. *Meets*, Third Friday. *President*, D. S. Cooper, 216 E. Cowan Dr. *Secretary*, A. M. Chase, Jr., Box 359. ***SOUTHERN CALIFORNIA:*** *Organized*, 1930. *Headquarters*, Los Angeles, Calif. *Meets*, Second Wednesday. *President*, H. H. Bullock, 212 N. Vignes St. *Secretary*, Leo Hungerford, 4851 S. Alameda St. ***WASHINGTON, D. C.:*** *Organized*, 1935. *Headquarters*, Washington, D. C. *Meets*, Second Wednesday. *President*, R. S. Dill, 1602 S. Springwood Dr., Silver Spring, Md. *Secretary*, J. W. Markert, 8506 Garfield St., Bethesda, Md. ***WESTERN MICHIGAN:*** *Organized*, 1931. *Headquarters*, Grand Rapids, Mich. *Meets*, Second Monday. *President*, F. C. Warren, 200 Division Ave., N. *Secretary*, H. D. Bratt, 228 Ottawa Ave., N. W. ***WESTERN NEW YORK:*** *Organized*, 1919. *Headquarters*, Buffalo, N. Y. *Meets*, Second Monday. *President*, S. M. Quackenbush, 117 W. Tupper St. *Secretary*, Herman Seelbach, Jr., 45 Allen St. ***WISCONSIN:*** *Organized*, 1922. *Headquarters*, Milwaukee, Wis. *Meets*, Third Monday. *President*, H. W. Schreiber, 507 E. Michigan St. *Secretary*, I. J. Haus, 5410 W. Center St.

Committee on Research

C. M. Ashley, *Chairman*

H. J. Rose, *Vice-Chairman*

C. M. Humphreys, *Acting Director*

J. H. Walker, *Technical Adviser*

A. C. Fieldner, *Ex-Officio Member*

Three Years: H. J. Rose, L. P. Saunders, L. E. Seeley, A. E. Stacey, Jr., C. Tasker.

Two Years: C. F. Boester, John A. Goff, W. E. Heibel, C. A. McKeeman, C.-E. A. Winslow.

One Year: C. M. Ashley, M. K. Fahnestock, H. King McCain, F. C. McIntosh, T. H. Urdahl.

Executive Committee: C. M. Ashley, *Chairman;* F. C. McIntosh, M. K. Fahnestock, H. J. Rose, T. H. Urdahl.

Finance Committee: E. N. McDonnell, *Chairman.*

Technical Advisory Committees

1. *Sensations of Comfort:* Thomas Chester, *Chairman;* N. D. Adams, C. R. Bellamy, G. D. Fife, E. P. Heckel, F. C. McIntosh*, A. B. Newton, B. F. Raber, C. Tasker*.

2. *Physiological Reactions:* R. W. Keeton, M.D., *Chairman.*

3. *Removal of Atmospheric Impurities:* R. S. Dill, *Chairman;* J. J. Burke, J. M. DallaValle, Leonard Greenburg, M.D., Theodore Hatch, W. C. L. Hemeon, L. R. Koller, C. A. McKeeman*, F. H. Munkelt, H. C. Murphy, G. W. Penney, E. B. Phelps, F. B. Rowley, J. B. Smith, W. O. Vedder, J. H. Waggoner, R. P. Warren, W. F. Wells.

4. *Radiation and Comfort:* J. C. Fitts, *Chairman;* E. L. Broderick, R. E. Daly, L. N. Hunter, F. W. Hutchinson, A. P. Kratz, John James, C. S. Leopold, D. W. Nelson, G. W. Penney, W. R. Rhoton.

5. *Instruments:* D. W. Nelson, *Chairman;* L. M. K. Boelter, E. L. Broderick, R. S. Dill, R. B. Engdahl, A. P. Gagge, J. A. Goff*, J. D. Hardy, A. E. Hershey, F. W. Reichelderfer, G. L. Tuve, C. P. Yaglou.

6. *Weather Design Conditions:* T. H. Urdahl*, *Chairman;* J. C. Albright, H. S. Birkett, P. D. Close, J. F. Collins, Jr., John Everetts, Jr., C. M. Humphreys, H. H. Koster, J. W. O'Neill, F. W. Reichelderfer.

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CONTENTS . . PAGE 67

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